# GEOMORPHOLOGY, SOIL AND LAND USE CHANGES IN THE MAHANADI-BALASAN INTERFLUVE ALLUVIAL FANS

Dissertation submitted to
Jawaharlal Nehru University
in partial fulfillment of the requirement
for the award of the Degree of
**Master of Philosophy**

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INDIA
1998

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# CERTIFICATE

21st July 1998

This is to certify that the dissertation entitled "Geomorphology, Soil and Land Use Changes in the Mahanadi-Balasan Interfluve Alluvial Fans" submitted by Arpita Sen in partial fulfillment of six credits out of the total twenty four credits for the award of the degree of Master of Philosophy of the University, is a bonafide work to the best of our knowledge and may be placed before examiners for evaluation.

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### *Acknowledgement*

*This dissertation embodied here could not have reached its culmination without the erudite guidance of Prof. K.S. Sivasami. The author is also indebted to Prof. Sudesh Nangia, Chairperson, Centre for Studies of Regional Development, and all other teachers of the Centre for their constant encouragement.*

*The author also expresses her gratitude to Prof. S.R. Basu, Dept. of Geography, University of Calcutta, for introducing her to the exciting field of alluvial fans.*

*The help rendered by Prof. Subimal Sen, Secretary and Dr. Partha Sarathi Chakraborty, Senior Scientist, Dept. of Science and Technology, Govt. of West Bengal, and NES, and National Remote Sensing Agency, Hyderabad, for helping out with Satellite imageries for preparation of land use maps is gratefully acknowledged.*

*The author thanks her friends and well wishers in North Bengal, who have helped in carrying out her field work successfully. The class fellows and the members of the computer division, CSRD, are also thanked for their help in completing this dissertation.*

*In conclusion the author records her gratitude to her family members for their constant encouragement throughout her work.*

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# CHAPTER I

# INTRODUCTION

For a long time in the development of geomorphology, alluvial fans received scant attention from geologists and geographers in comparison to that received by other landforms. Moreover, almost the entire emphasis on the study of alluvial fans has been restricted to those occurring in the arid and semi arid regions. Only in recent years the alluvial fans occurring in humid and subhumid areas are attracting attention of the geologists and geomorphologists. In India, alluvial fans occur under a wide range of environmental associations, depending upon the topographical and climatic conditions. The most common association of the fluvial environment where the alluvial fan deposits are associated with braided river depositions of the Himalayan mountainous region ( Datta, 1984). Alluvial fans are also found in the desert climates of Rajasthan associated with sand dunes and playa sediment. In glacial environments of the highest Himalayas, they are associated with glacial and fluvio-glacial deposits.

Prior to 1960, research on alluvial fans was characterised by lack of a common methodology and literature, resulting in relatively disjointed research efforts. Interest was generally confined to the geologic description of fan deposits, the establishment of fan classification criterion and terminology, and speculation about the depositional processes that form alluvial fans. Few researchers collected quantitative data on surface processes or morphology. The early 1960's marked a transition in alluvial fan research when quantitative studies became more prominent, that placed primary emphasis on fan process and morphology. Fan-basin relationships were used to suggest factors that control fan development (Leece, 1990).

Alluvial fans occurring the foot of the Himalayas have received very scant attention till date. A few studies have been carried out in a scattered fashion along the foothill of the Himalayas and these studies have morphologically characterised the fans. The studies on the Chandigarh-Dun alluvial fan (Mukherji, 1990), the Kosi megafan (Gohain and Parkash, 1990), the fans of Northern Brahmaputra (Datta, 1984) and the fans in the Darjeeling foothills area (Basu and Sarkar, 1990) are prominent studies on the fans occurring in the Himalayan foothills region.

Alluvial fans may be defined as stream deposits , the surface of which forms a segment of a cone that radiates downslope from the point where the stream emerges from the mountain area (Bull, 1963 and 1968). Some geomorphologists use the term "alluvial cone" to describe small fans steeper than 20 degrees that are formed by both fluvial deposition and mass wasting, while others have used it as a synonym for an "alluvial fan" (Leece, 1990). In this study, the term alluvial fan is restricted to those features deposited by fluvial processes and debris flow processes at the foot of hills and excludes other forms of mass wasting. Deposition on alluvial fans is commonly caused by a decrease in slope where a stream enters the apex of the fan (Blissenbach, 1954). The fans are derived from a source area with a drainage network that transports the erosional products of the source area to the fans in a single trunk stream. The result of fluvial deposit by the spring is a cone-shaped deposit.

An alluvial fan may consist of debris flow deposits, water laid deposits or both. The highest point of the fan where the stream leaves the confines of the mountains, is the fan apex. The overall radial profile of an ideal alluvial fan surface ( longitudinal profile) is concave, while the cross fan profile (parallel to the mountain front) is convex. In plan view, the deposit is typically fan shaped with contours that are convex outward from the mountain front (Bull, 1977).

Fans often have stream channels that are incised into the fan surface. Such trenching are generally deepest at the fan apex, the case known as " fan head trenching', and progressively decreases down fan until the stream channel and the fan surface intersect. This point on the fan surface is called the "intersection point". Alluvial fans may coalesce along a mountain front to form a depositional piedmont. Coalescent fans are frequently mistaken for pediments. However, alluvial fans are distinguishable as depositional features, while pediments are erosional landforms. In general, a fan may be distinguished from a pediment when the thickness of the deposit is greater than 1/100 of the maximum length of the landform (Bull, 1977).

The radial profiles of the fans are not smooth curves, but instead comprise three or four straight-line segments. The surface represented by these segments form bands of approximately uniform slope that are mainly concentric about the fan apexes. The fans are convex and the amount of convexity depends on where the profile is drawn and on the coalescing of adjacent fans. The central part of the fan is generally higher than the sides because of greater deposition on the central part (Bull, 1964). Alluvial fans and their source areas act as open system as changes in drainage basin conditions cause changes in drainage basin characteristics. The slope and area of a fan are related to the size and lithology of the drainage basin. Overall fan size is controlled by drainage basin features, such as, slope, rainfall and erodibility of the exposed rocks. Also fan area increases in about the same exponential manner as drainage basin area increases. The slope of the fan decreases with increase in fan area.

The important factors that affect fan morphology include (Kochel,1990):

1) The nature of dominant depositional processes, generally whether fan sediments are delivered by fluvial processes or by debris flow processes ;
2) The frequency of depositional events;
3) The rate of recovery or revegetation of hill slopes and fan surfaces following depositional events;
4) Lithology of source basin;
5) The degree of topographic restriction of the depositional site where fans are constructed; and
6) Post depositional modification of fan sediments by geomorphic processes operating in the vicinity.

Generally fluvially dominated fans are larger in size than the debris fans. While the fluvially dominated fans appear to be largely composed of sediments deposited by tractive bed load transport mechanisms in braided streams, the debris flow fans are formed by repeated depositional activity by debris flow processes. The North Bengal fans are mainly formed by stream action, and thus may be termed as fluvially dominated fans.

Rivers debouching from the Eastern Himalayas on to the wide open plains of North Bengal have developed a number of alluvial fans covering all the three districts of Darjeeling, Jalpaiguri and Cooch Bihar (Fig.I.1). They extend from the 300 meter contour in the north and further downslope they have coalesced to form a broad sloping alluvial- piedmont plain, known as the Terai-Duars plains in the foothills of the Eastern Himalayas. The Terai and Duars regions are situated respectively on the Western and Eastern parts of the River Tista, the main river of this region. Textural diversity has lead to the evolution of different land use and sediment patterns on each side of the Tista.

The piedmont plain present in a linear belt along the Himalayan foothills were given different environmental interpretations in earlier studies, e.g. a series of disconnected lakes (Gill ,1951), a longitudinal system of rivers (Gansser, 1964), and an environmental complex composed of piedmont, outwash plain, channel, flood plain and lake (Sahni and Mathur,1964). In a study by Banerjee and Banerjee (1982), the sedimentary deposits of the area were given a coalescing alluvial fan model. An alluvial fan model is defined by such parameters as the geomorphic-tectonic setting, the slope of the sediment body, a typical lithology, stratigraphy and paleocurrent pattern, a characteristic sedimentary structural assemblages and pattern of textural variation. The studies carried out in this area of Siwalik sediments conform to the alluvial fan model. The study shows that the Siwalik sediments of the Tista valley and adjoining area were deposited as an alluvial fan, the coarse pebbly sediments as debris flow deposits near the fan apex

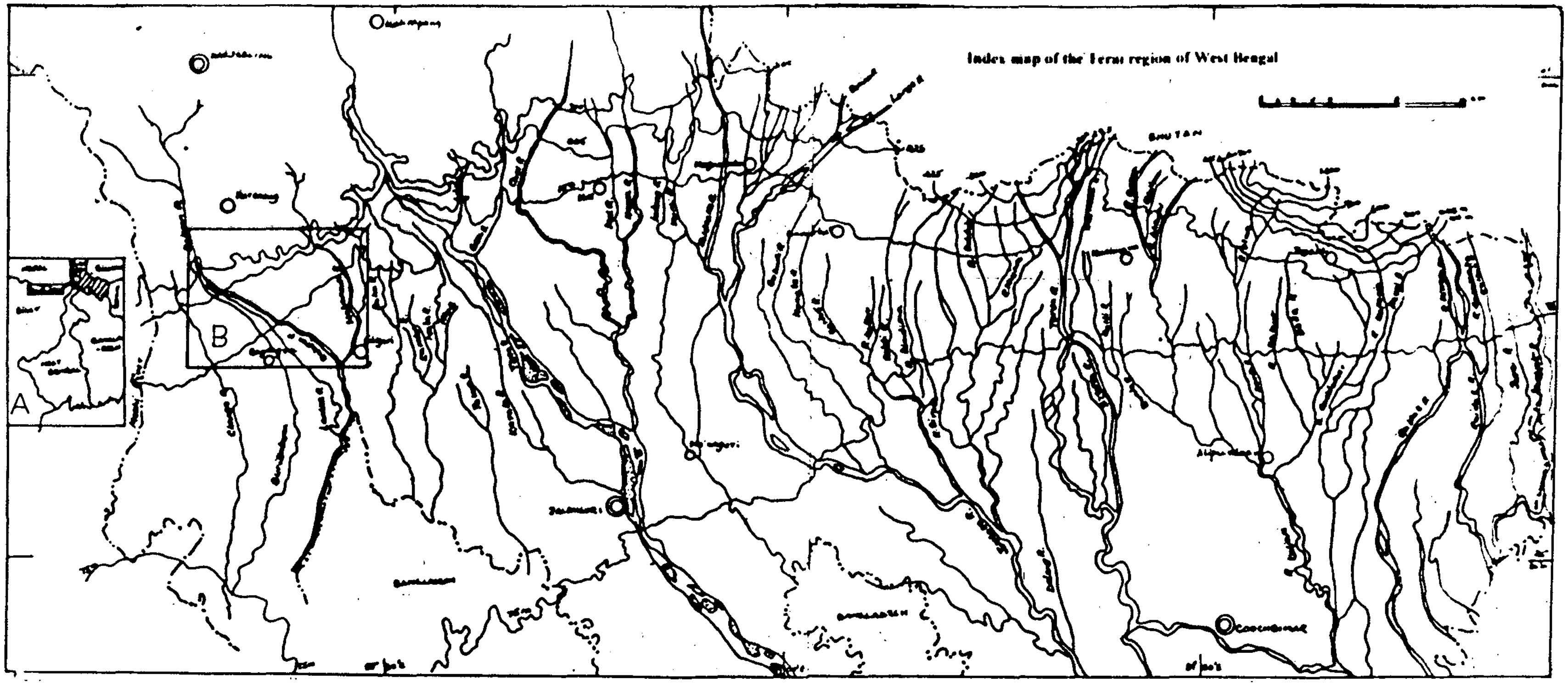



Fig I.1

INDEX MAP OF THE TERAI REGION OF WEST BENGAL

A LOCATION MAP
B STUDY AREA

and the medium sand stones and silt stones as braided stream deposits near the fan base. The morphological characteristics of the study area also establish the area as a coalescing alluvial fan area (Basu and Sarkar,1990). The contours of the region bow downslope from the fan apex, which is characteristic of alluvial fans. The radial profiles of the Rakti, Rohini and Mahanadi fans are all concave in nature and the cross profile convex. The longitudinal profiles have three distinctive bands of uniform slope representing the upper, middle and lower fan areas. The stream channels are entrenched into the fan head area, and below the fan heads, the rivers have formed braided channels. The coalescence of the fans formed by the Balasan, Rakti , Rohini and Mahanadi has formed a broad sloping piedmont plain. The area is neotectonically active (Sural and Das, 1992; Das and Chattopadhyay, 1993; Sural, 1994; Das, 1994;). The neotectonic movements in this area control the drainage pattern, topography and ground water distribution. The neotectonism is evidenced by the presence of terrace scarps and piedmont scarps that impart a step like appearance to the landscape.

The controls of development and the modes of deposition of the alluvial fans in the humid foothill region of the Darjeeling Himalayas give their distinctive characteristics.

a) Controls of development : The geometry of fans is strongly controlled by the factors of local relief, climate, lithology and the hydrographic characteristics of the streams. As the sediment laden mountain torrents exit from the steep, confined channels to flow on more gently sloping surfaces where the channels are no longer constrained to a fixed position, it result in decrease in stream grade and increase in channel width, decrease in the stream's power to transport the sediment load. As a result, the excess of sediment is deposited on the fan surface.

b) Modes of deposition: Intermittent flash floods, stream action, stream floods and mass movements are four notable modes of deposition on alluvial fans. The flash flood sediments are mostly deposited at and near the fan heads. The streams, upon entering the plains become unconfined and feed distributary channels, resulting in diminishing discharge along their courses. This favours braiding of the channels. The braided channels are incapable of containing the huge monsoon discharge in their reduced cross sectional areas, resulting in frequent floods in the rivers causing deposition on their respective flood plains. Extensive debris flows may move down the alluvial fans during the heavy downpours of the monsoon and may change the general slope of the fan heads.

c) Fan material and stratigraphy : The alluvial fan deposits are coarse grained, poorly sorted and immature sediments. Usually gravels and boulders predominate with subordinate amounts of sand, silt and some clay. Maximum grain size and thickness of sediments decrease rapidly towards the base of the alluvial fan deposits. Usually the rate of tectonic uplift in the mountains relative to the rate of stream channel downcutting largely determine the locus of deposition and the thickness of alluvial deposit (Bull, 1972, 1977). In the Eastern Himalayan fans, stratification is moderately developed. Boulder and pebble beds alternate with sandy, silty and muddy beds rich in organic matter, indicating the different phases of fan development. The boulder and pebble beds indicate flash flood and debris flow deposits, while the sandy , silty and muddy beds with finer sediments indicate stream deposits under calm condition.

## AIMS AND OBJECTIVES OF THE STUDY

The area of study is confined by the River Balasan on the west and the River Mahanadi in the east. In the north it stretches from the mountain front to the confluence of the two rivers in the south near Siliguri (Lat. 26° 43'N, Long. 88° 26'E). The area is formed by the coalescence of alluvial fans by the Balasan, the Mahanadi and the Rakti Khola and the Rohini Khola – tributaries of the Balasan. The area is bound by the latitudes of 26° 41' 30" N to 26° 52' N and longitudes of 88° 14'E to 88° 27' E, and cover an approximate area of 184 Sq. Km. At the beginning of the 19th century all these areas were under the dense cover of tropical vegetation. But, with the increase of population as well as prosperity, most of these areas have been deforested and turned into tea gardens, cultivated patches and settlements. This deforestation has led to increased rate of soil erosion especially in upper fan areas of the Balasan, Rakti and Rohini. However, the upper fan area of the Mahanadi still remains under forest cover, resulting in less soil erosion. Soil erosion in this area has been a combined result of rainfall pattern, soil characteristics and depletion of vegetation cover. Thus, one of the major aim of the study is to demarcate the zones of high, moderate and low soil erosion.

Land use on the fan surface is also on a constant change. From the dense forest cover of the early 19th century the area has undergone changes in its land use patterns with introduction of tea gardens in the area, which cover a large part of the study area in recent years. Percentage of cultivated area and areas under settlements has increased considerably with increase in population pressure. Thus, another major aim of the study is to see the trend in change in land use over the years and also to see if there is any correlation between land use change and soil erosion.

Soil erosion being established as one of the major problems of the study area needs to be checked by the introduction of sound erosion control measures. It implies obtaining the maximum sustained level of production from a given tract of land while maintaining soil loss below a level required to maintain the soil fertility in the medium term. Thus, the study also aims at recommending a detailed conservation practice for the different parts of the area under study.

## METHODOLOGY

In order to solve the problem of soil erosion and land use change on the different segments of the alluvial fan under study, the methodology followed includes :

1) Demarcation of the fans into upper, middle and lower segments. For demarcation of such segments, longitudinal profiles have been drawn from the apex of the fans to the fan bases. From the radial longitudinal profiles it can be seen that all the fans have distinct breaks in their slopes, which gives their radial profiles a segmented appearance. The fan segments generally have a constant slope and appear as straight lines on radial profiles. The surface represented by each of these segments makes a band of approximately uniform slope that run concentrically away from the fan apex. Vertical exaggeration is necessary to show clearly the segmented shape of the radial profiles.
2) Demarcation of erosion prone areas – Within the study area, the main erosional hazard of soil has been stemmed from the action of water. The quantification of such soil loss has been based on the method of the Universal Soil Loss Equation (USLE) with necessary modifications. Thus, the average annual soil loss of the area under study is evaluated as the multiplied functions of the various diagnostic factors like a) climatic erosivity or rain erosivity ( R) b) the soil erodibility (K), c) the topographic erosivity (LS), and d) the biotic factor (CP). The first three factors, i.e. R, K and LS may be designated as physical factors. The biotic factor, CP, include the effect vegetation cover, land use, human interference, etc. and thus gives an account of the loss resulting from cultural environment. The combination of both the physical and cultural factors, permit to estimate the predicted annual soil loss.

3) Land use change – For studying the changing land use of the area, toposheets and satellite imageries at different time points have been consulted. The base map is prepared from the toposheet and changes in land use in the 1990's have been studied from satellite imageries with help of visual interpretation method. Field checks have been done in order to identify different land cover present in the area. The quantitative analysis of land use change has been done with the help of Census data for 1971 and 1981. Census data has not been updated in 1991.

SOURCE OF DATA:

Data required for carrying out this study are collected from two sources : 1) Primary and 2) Secondary. The geomorphology of the alluvial fans was studied using mainly the topographical sheets no. 78B/5 and 78B/6 on 1:50000 scale. These are supplemented by field survey and data available from published and unpublished reports. The soil data is primarily obtained from the work done by Sarkar and wherever necessary the additional data was collected on the field. Rainfall data have been obtained from IMD for the Siliguri station and additional rainfall data were obtained from Government departments and non- Government organisations. Satellite imagery IRS1B LISSII on a scale of 1:50000 for the years 1990, 1994 and 1997 from NRSA were used for deducing land use changes. Village level land use data for the years 1971 and 1981 have been obtained from Darjeeling District Census Handbook.

INTRODUCTION TO THE STUDY AREA

Darjeeling is the northernmost district in the state of West Bengal. The district has been so named after its chief town Darjeeling, a picturesque hill resort, which in turn is named after 'Dorje-ling', meaning place of the 'Dorje', the majestic thunderbolt of the Lamaist religion.

The district of Darjeeling lies between 26°31' and 27°13' N latitudes and between 87°59' and 88°53'E longitudes, covering an area of 3004 sq. km. The principal town and administrative head quarter of the district headquarter of the district is Darjeeling. In shape, the district is an irregular triangle. The northern boundary commences on the west at the peak of Phalut nearly 3660 mt. high, the tri junction of the boundaries of Nepal, Sikkim and India. On the west the district is bound by Nepal. From Phalut the western boundary follows the southward ridge until it joins the Mechi River, which continues right upto the southwestern corner of the district. On the south lies the district of Purnea (Bihar) and West

Dinajpur (West Bengal) intercepted by the Mahanadi River and on the east the district is bound by Bangladesh and the Jalpaiguri district.

NATURAL DIVISIONS:

The district consists of a portion of the outlying hills of the lower Himalayas and a stretch of territory lying along the base known as the Terai. The hills rise abruptly from the plains and the elevation increases northwestwards. The mean elevation of the Terai is 91 .44mt above sea level, while some of the hills within the district rise to more than 3000 mt.

The physical configuration of the Darjeeling Himalayas is partly due to the direction of the main drainage, which is southern, and mainly due to geologic structure, which is a dominant controlling factor in the in the evolution of landforms. The northern portion consists of hard gneissic rocks capable of resisting denudation to a considerable extent, while the southern portions comprise of comparatively soft, thin, platy and half schistose rocks which are less resistant to erosion.

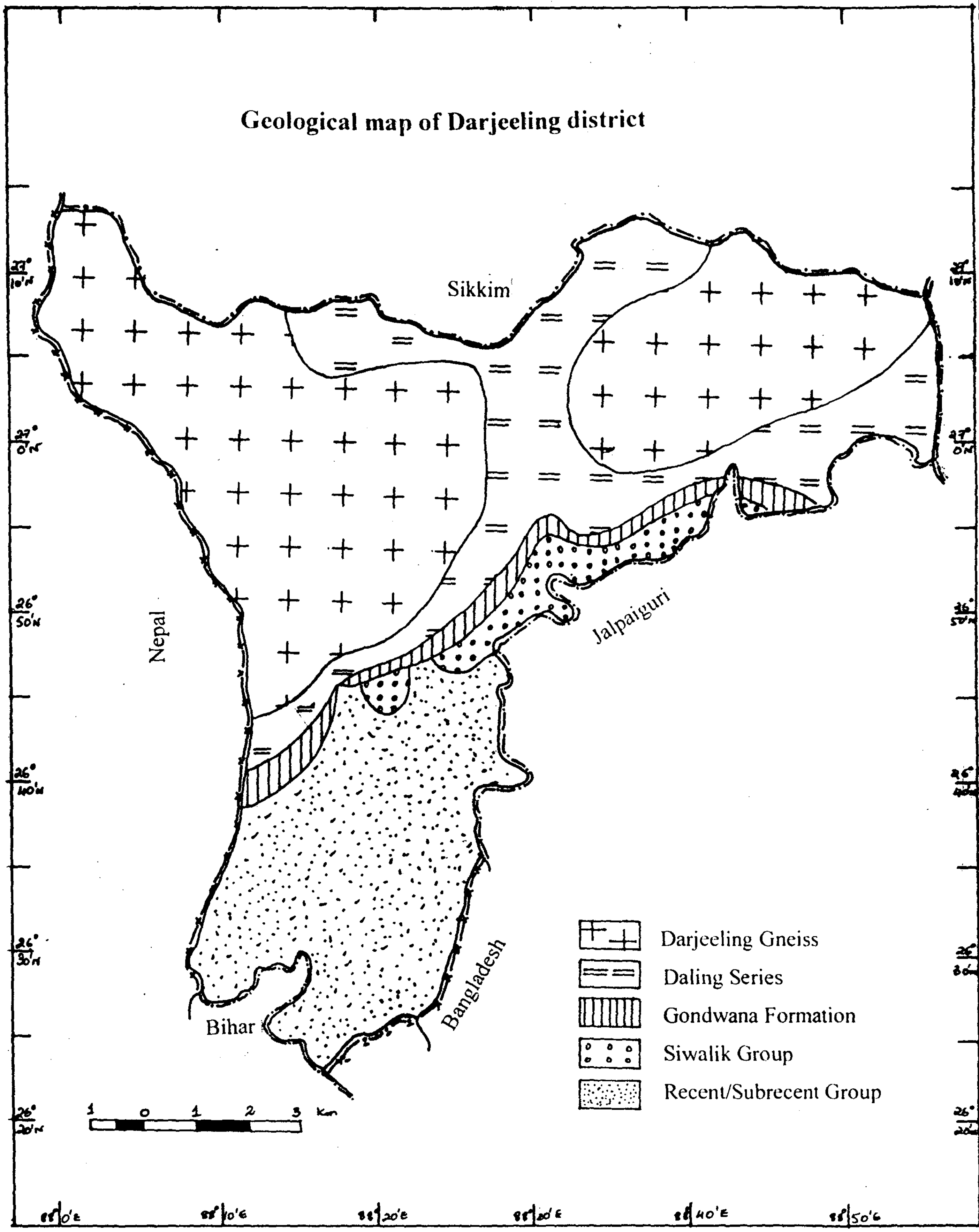
The Terai lies between the mountains and the plains and is traversed by numerous hill streams. Geologically it is sort of a neutral country, being composed neither of the alluvium of the plains, nor of the rocks of the hills, but for the most part of the alternating beds of sands, gravels and boulders brought from the mountains. it is traversed by numerous rivers and streams flowing out of the hills; it is unhealthy and at places marshy. The Terai soil is generally light, dry and gravelly. In between the river channels lie gravel beds extending upto 32 Km. south from the base of the mountains. The plains portion of the Darjeeling district lies between 26°30' and 26°45'N latitudes and 88°15' and 88°30'E longitudes. The general slope is from north to south. The rivers describe meandering courses and their beds are sandy. The topography is almost flat and monotonous. Human settlements follow the gradient; the pattern is linear from north to south and they avoid the immediate neighbourhood of the bigger streams, which are liable to sudden floods

GEOLOGY:

Geologically the district may be divided into four tracts, which are, from north to south, the hard rock area, the bhabar belt, the terai belt and the alluvial plains. In the hard rock region, the southern portion is covered with sedimentary rocks while the northern part is composed of different grades of metamorphic rocks (Fig.I.2).

The great Himalayan range was elevated during the Tertiary period, on the site of an ancient sea that had accumulated sediments of different geological ages. The mountains are made of folded rocks piled one over another by a series of north-south horizontal compression movements and tangential thrusts, which also folded the strata on the sea floor and caused their upheaval by stages. At many places, the formation has been intruded by granites.

The products of the disintegration of the mountains have been swept over the submontane tract as the rivers debouch into the plains. The Terai and the plains at the foot of the Himalayas were given their present form after the final upheaval of the range and consist of almost horizontal layers of unconsolidated sand, silt, pebbles and gravels. The foothills, north of the Terai, are made of similar but well cemented and more compact alluvial detritus consisting of soft, gray massive sandstone, mudstones, shales, mottled clays, conglomerates and subordinate bands of earthy limestone and lignite. The rocks are of Tertiary age and have been included in the Nahan stage of the Siwalik system of the outer Himalayas. The highest hills are composed of mica schists and gneisses, known as the Darjeeling gneiss, which are partly sedimentary and partly igneous in origin. To its south lies the Daling series, formed mainly by a group of low grade metamorphosed sediments like quartzites, slates, phyllites and foliated rocks composed of flaky



Geological map of Darjeeling district
Sikkim
Nepal
Jalpaiguri
Bihar
Bangladesh
Darjeeling Gneiss
Daling Series
Gondwana Formation
Siwalik Group
Recent/Subrecent Group


Fig. I.2.

minerals like graphite, chlorite and sericite. The Gondwana formations are found in a narrow band between the Dalings in the north and the Siwaliks in the South.

## SOIL:

The soils found in the hills are coarser, while those found on the plains are finer and more fertile. The areas lying in the flood plains of the rivers get fresh deposits of fertile sediments in years of floods. The soil in the Terai is composed of alluvium, light sandy loam being the most common. There are also considerable tracts of sandy or gravelly soils, unsuitable for cultivation. River alluvium is found in the southernmost part of the district. The area bound by the Mechi in the west and the Mahananda in the east, is stretching from the southern boundary of the district to about 10 Km. north of Siliguri, is entirely covered with alluvium consisting mainly of sands and silts brought down by the streams. The commonest form of alluvial soil in this area is light sandy loam, the fertility of which varies according to its different types.

## RIVER SYSTEM:

The rivers of the districts drain ultimately to the south, though the west to east ridge across it causes a series of Tista tributaries rising on its northern face to flow northwards and others flow east or west before joining the main river. Dominating all the other rivers in the district is the Tista which rises in a glacier in north Sikkim, 6400 mts. above sea level, and drains the whole of Sikkim and the hilly parts of the Darjeeling district and it leaves the district at Sevok and ultimately meets the Brahmaputra in Bangladesh. In Darjeeling district, its principal tributaries are the Rangpo and the Rilli on its left bank and the Great Rangit, the Riyang and the Sevok on the right bank.

East of the Tista, are rivers debouching from the foothills, which, like it, flow into the Brahmaputra. The most important of these eastern rivers is the Jaldhaka and carries the largest volume of water of all this group of eastern foothill rivers. Those nearest the Tista, the Lish, the Gish, and the Chel emerge from the hills carrying great volumes of stones, mud and sand torn from there catchment areas by erosion and landslides.

The rivers to the west of Tista, the Mahanadi, the Balasan and the Mechi all flow into the Ganga. The Mahanadi has its source near the Mahaldiram dome, east of Kurseong, and flows south eastwards receiving only one or two sizeable right bank tributaries, but more than five important left bank tributaries descending from the Latpanchar dome. The river attains its full girth after leaving the Terai portion of the district. Just below Siliguri the Mahanadi receives the Balasan on its right bank and thereafter describes wide meanders over a wider bed. Rainwash or sheetwash has contributed in the case of this river to valley widening while features of gullying are also noticed on valley sides from 115 mt. To 105 mt. The cross profile of the valley is asymmetrical due to meandering and lateral erosion. The parallel drainage texture of the planes built up by the Mahanadi and its effluents are naturally dependent on the existing relief with a very low gradient. The slope is concave in general. Above Siliguri, where sheet wash and large scale erosion are not very effective due to the dense canopy of the Terai forests, there are very few stream courses. But, beyond the forest limits there are numerous channels running parallel to each other. Below Phansidewa only incipient stages of meander development are noticed. The floodplain materials consisting primarily on finer alluvium, have a thickness exceeding the depth of the river channel but beneath this finer alluvium, there are coarser materials representing channel deposits made at various positions occupied by the stream as it migrated laterally over its valley flat.

Through the interfluve between the Mahanadi and the Balasan run the road and rail routes to Darjeeling. The Balasan rises from Lepchajagat Peak on the Ghum saddle and flows south almost parallel to the $88^{\circ}$ 15' E meridian till it reaches the planes at an altitude of 304.8 mt. And then turns south east where its valley is larger than the Mahanadi, although it does not receive so heavy a rainfall. On entering the Terai it divides itself into two channels, one called the New Balasan which joins the Mahanadi just below Siliguri, and the other, the Old Balasan, continues southward and passes out of the district to join the Mahanadi lower down. Below Kurseong the main tributaries of the Balasan are south flowing. They are, from west to east, the Rungsung Khola, the Rakti Khola and the Rohini Khola, all of which have scooped out deep gorges though they have very small catchment areas in the hill. The Rakti, in particular, cuts a cliff ranging from 15-35 mt composed of stratified sand and water- worn gravel.

## ORGANISATION OF CHAPTERS

The present study **"Geomorphology, soil and land use changes in the Mahanadi- Balasan interfluve fan areas"** attempts at establishing a relationship between the physical conditions prevailing in this vast piedmont tract formed by coalescence of alluvial fans and land use changes. The morphology of the fans, the drainage characteristics, soil erosion along with increasing population pressure and establishment of defence estates affect the nature of land use changes in the area. The different aspects of physical conditions and the land use change have been discussed in detail in the following chapters.

The first chapter, **Introduction**, deals with the objective of the study, the methodology followed, the data source and the previous literature. This chapter also gives a brief description of the district within which the area of study lies. The second chapter, "**Characteristics of the interfluve fans -Balasan and Mahanadi**" describes the drainage characteristics of the area and how drainage helps in modifying the landform. The geomorphology of the study area, including fan morphology and the geomorphological processes has been discussed in detail and from this, an inference has been made about the possible evolution of the fans. Chapter three "**Soil and soil erosion in Balasan-Mahanadi interfluve alluvial fans**" describes the soil characteristics of the area. The soil type varies from the upper fan areas towards the fan base, depending on their distance from the fan apex. This varying soil type has a bearing on the type of land use prevailing over the area. Chapter four "**Rainfall characteristics**" describes the general rainfall condition prevailing in the area and how it helps in soil erosion. Rainfall is the main factor causing soil erosion being modified by other factors like slope, soil condition and land use. The study area has been divided into four zones of erosion. Chapter five "**Changes in land use of the interfluve fans-Balasan and Mahanadi**" elaborates on the nature and causes of the land use change in the area. The major change is in depletion of forest cover to be replaced by cultivated area caused by the establishment of defence estates and by increasing population pressure over the area. The final chapter, "**Conclusion**", summarises the findings of the above mentioned chapters and tries to correlate the land use change to soil erosion, increase in population pressure and establishment of defence estates.

# CHAPTER II

# GEOMORPHOLOGY AND DRAINAGE CHARACTERISTICS ON THE FAN

The area of study is bound on the west by the **Balasan river,** having its origin in the Lepchajagat peak on the Ghoom saddle and the **Mahanadi**, originating from the Mahaldiram dome, to the east of Kurseong. Just below Siliguri, the Mahanadi receives the Balasan on its right bank. Thus, the study area lies between the foothills in the north and the confluence of the rivers Balasan and Mahanadi near Siliguri in the south. The geomorphology of the area under study are guided by the different factors like the geological setup of the area, the drainage system prevalent in the area, the effects of continued tectonic activity that lead to the continuance of natural hazards of this area, *viz.,* flood, water logging, soil erosion etc. The river channels have often changed their courses that are evident from escarpments that lie away from the present day channels. There have been significant changes in the landscape due to the continuance of neotectonic activities. The long profiles of the alluvial fans often show significant breaks in their slopes, and the changing slopes along their profiles help in dividing the alluvial fans into three distinctive segments of the upper, middle and lower fan areas, which have their own individual characteristics.

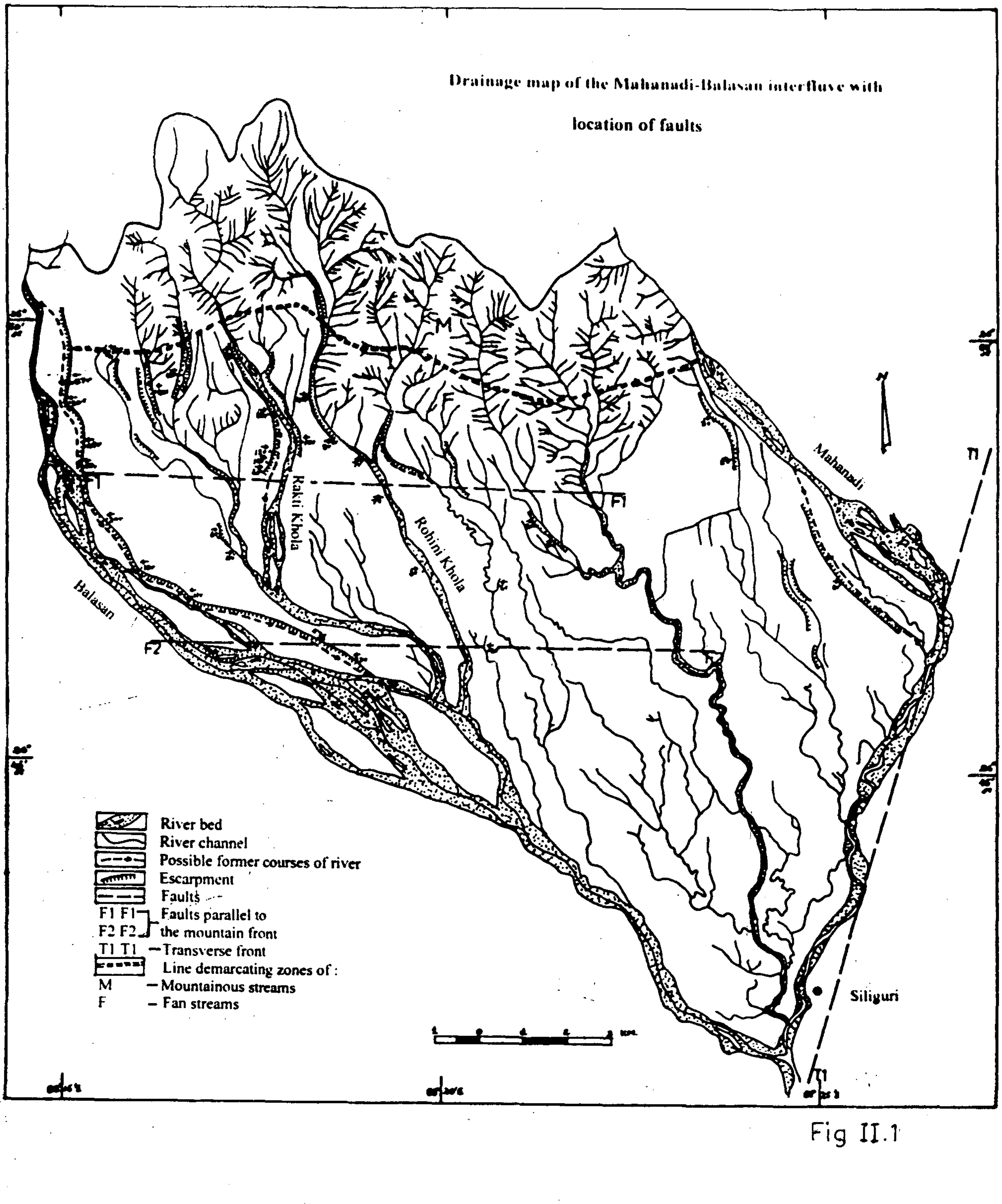
## DRAINAGE CHARACTERISTICS ON THE ALLUVIAL FANS

The rivers of the district drain southwards, having their origin in the high Darjeeling Himalayas. The Mahanadi river attains its full girth after leaving the Terai portion of the district. The part of the river flowing through the mountainous part has deep winding course, but after entering the plains, rainwash and sheetwash has contributed in the widening of the river bed. Features of gullying are noticed on valley sides from 115 mts. to 107 mts. altitudes. The cross profile of the valley is asymmetrical due to meandering and lateral erosion. The Mahanadi and its effluents have developed parallel drainage texture, which resulted from the existing relief with a very gentle slope. Number of streams are very few above Siliguri where sheet wash and large scale erosion are not very effective due to the dense canopy of the Terai forests. But beyond the forest limits there are numerous channels running parallel to each other. The floodplain materials consisting primarily of finer alluvium have coarser materials underneath, representing channel deposits made at various positions occupied by the stream as it migrated laterally over the valley flat.

The Balasan river, after rising from the lepchajagat peak flows southwards almost parallel to the 88° 15' E meridian till it reaches the plains at an altitude of 304.8 mt. Here the river turns southeast wards and the valley of the river is broader than the Mahanadi, although it does not receive so heavier rainfall. On entering the Terai it divides itself into two channels, one called the New Balasan which joins the Mahanadi just below Siliguri, and the other, the Old Balasan, continues southwards and passes out of the district to join the Mahanadi lower down. The channel of the river New Balasan forms the western boundary of the study area. Below Kurseong the main tributaries of the Balasan are south flowing. They are, from west to east, the Rungsung Khola, the Rakti Khola and the Rohini Khola. All these tributaries have formed deep gorges, though they have very small catchment areas in the hill. The Rakti in particular, cuts a cliff ranging from 15-35 mt. composed of stratified sand and water-worn gravels.

## EVIDENCES OF NEOTECTONISM

The direction of flow of main rivers, their tributary streams and small channels are all guided by the parallel and transverse fault systems present in the area. Two sets of faults have been identified here (Fig. II.1), one parallel to the main trend of the Himalayas, which are present on the surface as normal faults, and the other, oblique to the main trend of the Himalayas occurring as strike-slip faults. On a number of occasion the normal faults were found to have affected the fan terraces (Sural and Das, 1992). The two most prominent thrusts- the Main Boundary Fault in the north separating the Siwaliks and the Pre-Siwaliks, and the Main Frontal Thrust or the Foothill Thrust in the south between the Quaternary and Pre



Drainage map of the Mahanadi-Balasan interfluve with
location of faults
Mahanadi
Rakti Khola
Rohini Khola
Balasan
M
F
F1
F2
T1
Siliguri
River bed
River channel
Possible former courses of river
Escarpment
Faults
F1 F1 Faults parallel to
F2 F2 the mountain front
T1 T1 —Transverse front
Line demarcating zones of :
M —Mountainous streams
F – Fan streams


Fig II.1

Quaternary rocks have been mapped along the foothill (Sural, 1994). The Main Boundary Fault (MBF) has been observed to be dissected/displaced at a few localities along the northerly trending faults. The neotectonic movements along these faults control the drainage pattern, topography and ground water distribution in the whole North Bengal plains (Das & Chattopadhyay, 1993). The escarpments present among some of these rivers also point to neotectonic activities. Various evidences including physical, morphological and ground water potential point to the neotectonic activity in the area. The most interesting geological evidences ascertaining neo tectonic movement include- 1) appearance of gap areas in respect of Siwalik sedimentation, 2) The vertically and horizontally displaced Quaternary strata along faults, 3) Occurrence of well defined zones of faults were pushing off Quaternary sediments along with older rocks were observed, and 4) Appearance of "erratics" over wide areas comprising very large and angular boulders floating in finer clastics indicating a young morphogenetic uplift of the Himalayas. The highly abnormal behaviour of the streams with antecedence and stream capture as observed in a number of locations in the North Bengal plains are strongly suggestive of continued tectonic activity.

## EFFECT OF NEOTECTONISM ON DRAINAGE PATTERN

An east-west trending scarp is seen north of Garidhura below Bamanpokri Reserve forest, which cuts across the course of the Balasan River and number of streams, viz., Rungsung Khola, Rakti Khola and Rohini Khola. Below this scarp the rivers attain an unconfined condition. This condition may appear if the depression on the downfaulted side is in the flow direction of the streams, The streams tend to fan out on the downfaulted side. Above this separating piedmont scarp, these rivers have incised vertically into the landform as a consequence of the uplift due to neotectonic movements (Das and Chattopadhyay, 1993).

Uplift in the downstream direction invariably produces a temporary barrier to the flow of water. Thus, depending on the lithologic conditions, the barrier may reveal itself as a scarp face or just a lineament traceable along identical bends of rivers and nullahs, which may result in river diversions. Such river diversions along a linear trend are also observed around Phulbari. A nearly west-east trend in the Rakti Khola and other nullahs bounding the New Champta Tea Garden and the west north west – east south east diversion diversion of the Balasan along a similar trend are believed to be an expression of a barrier that cuts across a number of rivers. Such a barrier causing an obstruction in the southerly flow of rivers is believed to be tectonically motivated, possibly caused by upfaulting of the southern block.

Apart from these faults parallel to the Himalayas, lineaments that are transverse to the Himalayan trend are common in Eastern Himalayas. One such transverse fault falling within the study area is evidenced by the straight north-north east to south -south west course of the Mahanadi between Siliguri and Titalya. This may be represented by a lineament continuing with the Gulma nullah to the north -north east. The Mahanadi and Balasan are both diverted to the south- south west along the line. This lineament is, thus, a fault whose eastern block is upthrown. This lineament has also been identified by the ONGC through seismic studies.

The neotectonic network contributes a great deal to the instability of the region such that the maze of rivers and nullahs keep constantly changing their direction. These changing courses of the rivers are evident from the presence of the escarpments that lie away from the present channels. An attempt has been made in the present study to construct the possible former course of the rivers (Fig. II.1). From the study it is evident that the Balasan has shifted its course in a southwesterly direction, leaving very broad riverbanks at places. The Rakti Khola has shifted its course eastwards to the east of Garidhura. Above the piedmont scarp, below which the river has become unconfined, the river has shifted its course slightly eastwards.

Due to neotectonic movements, erosive capacity of the rivers increase and the erosion of the material from the uplifted areas and their subsequent deposition in the downfaulted depressions has been a continuous cause of the aggradation and shifting of rivers. This, in turn, is one of the primary causes of floods in this region through ages.

Based on the source area, the streams that flow on the fan can be classed into two categories: 1) those originating from the Himalayas and 2) those originating on the fan.

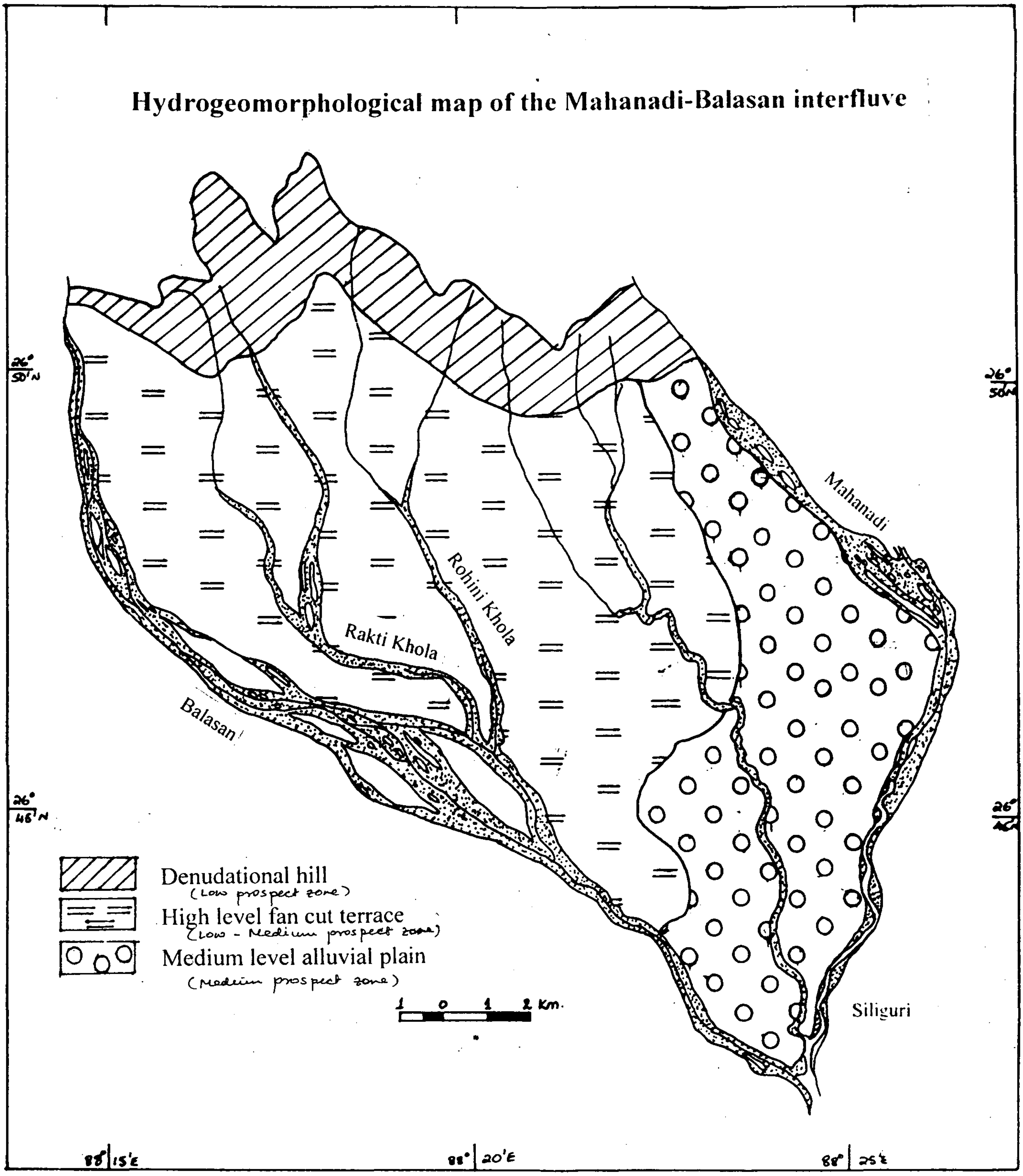
The mountainous streams: The streams belonging to the former group originate from the south facing Himalayan slopes and these are all tributaries to the axial streams. These streams are mostly first order streams. Most of them originate in the mountainous parts and meet their parent rivers within the mountainous reach only. Some of these streams come out of the mountainous reach and meet the axial rivers on the plains. These streams are wholly consequent in genesis and are younger than the age of the alluvial fan. These streams have such insignificant discharge, that although they dissect the fan they do not contribute to the alluvial building of any part of the fan, except to a limited extent at the slope base.

The fan streams: The second category of streams, i.e. the fan streams, have their origin in different parts of the upper, middle and lower fan areas. These streams are also consequent in nature and a large number of such streams either merge with each other or with the main rivers flowing through the area. These streams have further added to the fineness of the topographic texture of the fans. They are younger in age than their Himalayan counterparts. They are formed by the reappearance of water beyond the zone with coarse soil texture where water gets readily infiltrated into the soil mainly in the upper and to some extent in the mid portions of the fans. When this infiltrated water encounter a less porous soil with higher quantity of finer materials it reappears on the fan surface and if the reappearance is on a sloping ground, a stream is initiated. This zone of reappearance is locally known as "Chosh" zone. These streams have seasonal intermittent flow and are to some extent rain fed in nature.

The rivers have typical V-shaped valleys in their mountainous reaches above the fan apex, but just below it the shape of the valley change having deep box like cross profiles, where the axial streams are deeply entrenched into the fans. In this reach, stretches of graded channels can be seen, which are related to decline in gradient and decline in discharge. The valley walls are as high as 50 meters along the Balasan River and the Rakti Khola at places, and have even attained heights of 67 meter in the upper reaches of the Rungsung Khola, which is a tributary of Rakti Khola. These valley walls lose their height away from their fan apex towards the lower fan areas, where the rivers attain flattish wide beds. The depth of entrenchment is reduced to 2-3 meters in the lower parts of the mid fan area along the Balasan near Phulbari. In case of other rivers also, they are mainly confined within mid fan area. In the lower fan areas, such entrenchment is totally absent. Floods affect the lower parts of the fan area in years of unusually high discharge.

## UNDERGROUND WATER CONDITION

The Terai region, covering parts of the Darjeeling, Jalpaiguri and West Dinajpur districts, in general have low drainage density with a gentle slope towards south. Poor drainage density and coarse constituents indicate low run off and high permeability of the area. This area have been thoroughly surveyed by the Geological Survey of India by drilling bore holes in different locations to explore possibilities of ground water occurrences (Goswami et al,1976). Also, hydrogeomorphological maps have been prepared using remote sensing techniques as satellite imagery depicting spectral information on various hydrogeomorphological units having different ground water potential (Duarah et al , 1993, Fig.II.2).



Hydrogeomorphological map of the Mahanadi-Balasan interfluve
26° 50'N
26° 50'N
26° 46'N
Mahanadi
Rohini Khola
Rakti Khola
Balasan
Denudational hill
(Low prospect zone)
High level fan cut terrace
(Low - Medium prospect zone)
Medium level alluvial plain
(Medium prospect zone)
1 0 1 2 Km.
Siliguri
88° 15'E
88° 20'E
88° 25'E


Fig. II.2

The entire study area can be divided into two categories of potential areas –

1) denudational hills of Siwalik group and
2) alluvial region.

The main constituents of the rocks of the first area are moderately hard, coarse grained sandstone. Due to lack of porosity and sufficient fractures, no aquifer zone exists within this unit, situated in the extreme northern part of the area. This is mostly a run of zone.

The second unit, i.e. the alluvial region is again subdivided into two separate units depending upon the topographic characters. These are-

a) high level fan cut terraces of piedmont zone and
b) medium level alluvial plain.

The entire piedmont zone within the study area is built up by the coalescence of a number of alluvial fan, formed by coarse materials carried by the rivers from the higher Himalayas. Due to river action, terraces have developed in the first subzone of high level fan cut terraces, covering the western part of the study area. At places, these are 7-9 mt. in height above the medium level alluvial plane with a gentle slope towards south, which gradually merges with the second unit. Mostly tea gardens and forests cover the high level fan cut terraces. This area consist mainly of unconsolidated boulder, gravel, pebble, cobble, and sand with subordinate amounts of silt and clay. The individual grain size of the constituents gradually diminishes towards south. The streams are mostly of ephemeral type. The gentle slope and the unconsolidated coarse constituents of the area make it a very good recharge zone. From bore hole studies it appears that during the premonsoon period water level goes down to a depth of 5-14 mt. below ground level and in the monsoon period it comes up to a level of 0.5- 2.5 mt. below ground level. In the piedmont zone ground water occurs under waterable condition as discontinuous unconfined aquifers.

Medium level alluvial plain covers the eastern and southern parts of the study area. The area is covered by a few tea gardens, pineapple gardens, other agricultural plantations and cropland. The area represents an almost flat or slightly undulating surface. It is situated at a slightly lower level than the high level terraces. Palaeochannels are well preserved in it. Drainage density is very low. Bore hole data indicates that the different pervious layers of gravel sand and silt and impervious clay layers were deposited alternately resulting in aquifer zones at various depths. The ground water table varies between 3-5 meter below ground level.

The ground water is sufficient in the study area underlain by a piedmont type of alluvial material ranging from fine sands to the coarsest of pebbles and even boulders as major fraction of the rainwater percolates through the ground enriching the ground water reservoirs. However, difficulty arises in regard to its exploitation due to the presence of large boulders that are encountered during drilling.

## GEOMORPHOLOGY AND THE GEOMORPHOLOGICAL PROCESSES

The morphology of the area between the rivers Balasan and Mahanadi is mainly shaped by fluvial action. The main rivers of the region along with their tributaries, deposit unassorted sediments at the base of the Darjeeling Himalayas forming the alluvial fans. These rivers have cut deep gorges at their respective fan heads, but upon their emergence onto the fan surface, they are free to subdivide and become unconfined in the down fan areas forming wide braided channels. Thus, on the fan surface the trunk streams feed distributary channels and discharge diminish along their courses, which ultimately results in the rivers becoming incapacitated (Table 2.1).

Table 2.1: Discharge of the rivers on the alluvial fans

| River | Location | Average discharge ($m^3s^{-1}$) | |
|---|---|---|---|
| | | Maximum | Minimum |
| Balasan | Dudhia | 1500 | 2.15 |
| Rakti | W.Simalbari | 150 | 0.31 |
| Rohini | E.Simalbari | 160 | 0.40 |

Source: Basu and Sarkar, 1990

These braided channels are quite incapable of containing the huge monsoon discharge in their reduced cross sectional areas and cause major floods in times of excessive rainfall, causing deposition on their respective flood plains in the middle and lower parts of the fans.

Apart from such fluvial processes, flash floods and debris flows also contribute sediment load on the fan surface. Flash flood deposits mainly accumulate at and near the fan heads and such deposits are unsorted and coarse-grained sediments. Debris flow mainly occurs during the heavy downpours of the monsoon and may change the general slope of the fan heads. Debris flows even bring huge boulders from the adjoining deforested hills and deposit them in the fan head areas, as in Marchenbong, the fan head area of the Rohini Khola.

For examining the configuration of the fans, radial and longitudinal profiles are useful. The radial profiles of an alluvial fan reflect its depositional history, which is controlled partly by erosional and tectonic changes in the drainage basin upstream from the fan. The radii of a fan are restricted by adjacent fans. The overall radial profiles of alluvial fans are gently concave upwards(Fig.II.4). The slopes of alluvial fans decrease gradually away from the mountain front. The

**Radial profiles along the alluvial fans**

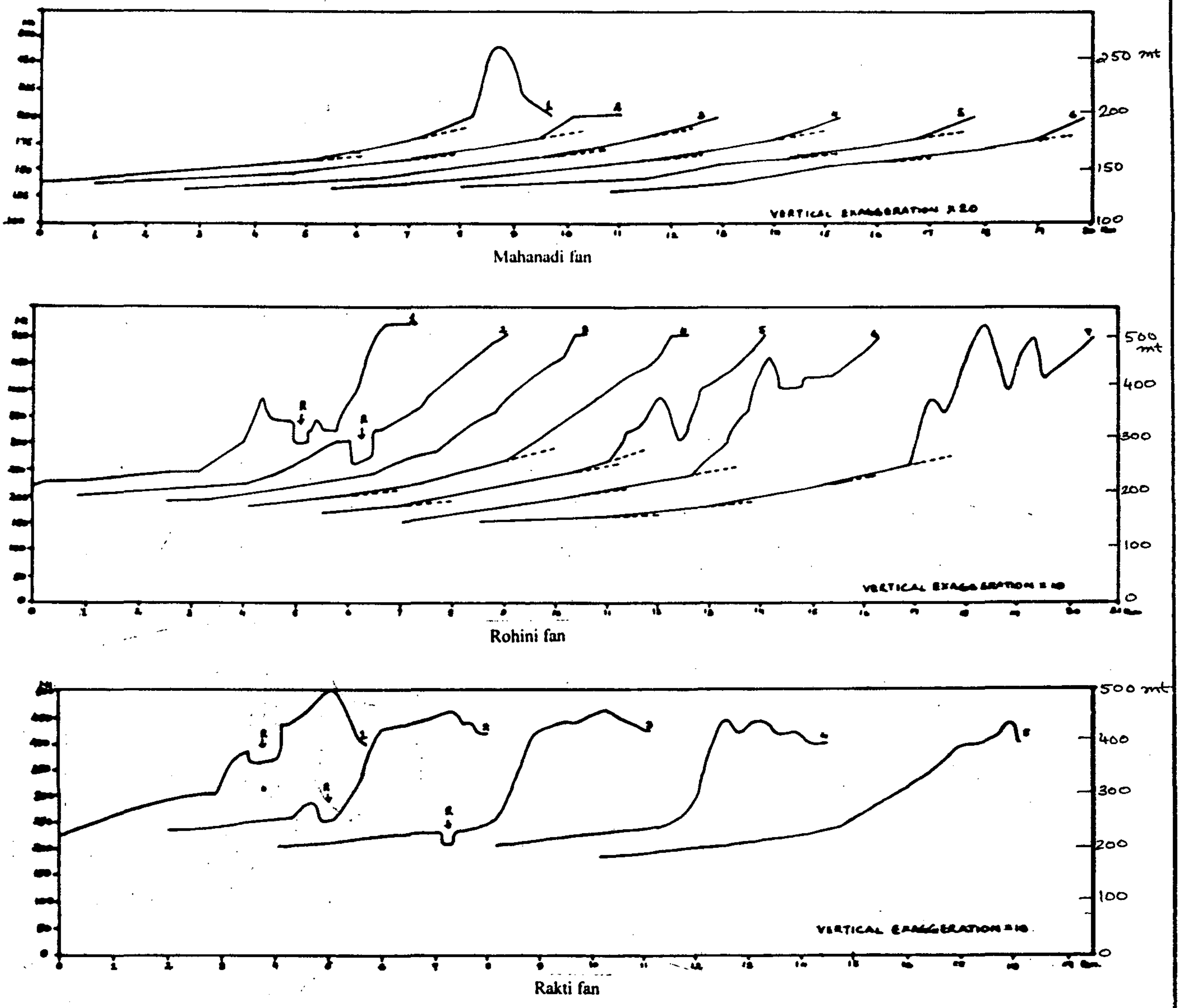



Fig. II.3

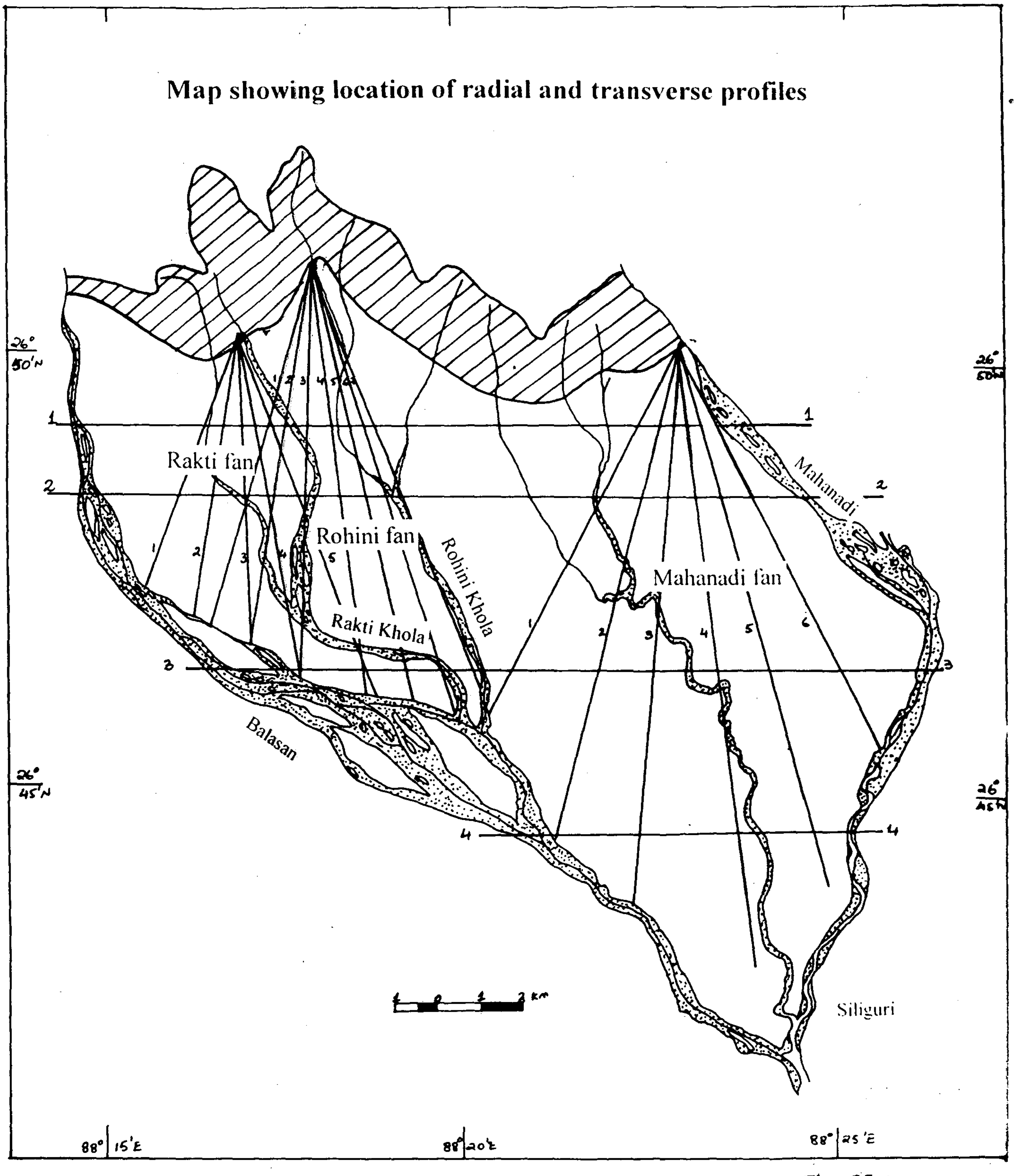

Map showing location of radial and transverse profiles
Rakti fan
Rohini fan
Mahanadi fan
Rakti Khola
Rohini Khola
Mahanadi
Balasan
Siliguri
26°
50'N
26°
45'N
88° 15'E
88° 20'E
88° 25'E
km

Fig. II.4

general slope of the fan surfaces in the study area is from north to south. The fans have distinct breaks in the slope, which give their radial profiles a segmented appearance. The surface represented by each of the segments makes a band of approximately uniform slope that runs concentrically away from the fan apex.

The longitudinal profile reveal that the Mahanadi (Fig.II.3, 1-6) and Rohini (Fig.II.3, 1-6) fan surfaces are more regular than that of the Rakti (Fig.II.3, 1-4). The first two have subdued concave zones, whereas the maximum irregularity is displayed in the Rakti profiles in the form of humps and shallow depressions. In different profiles the slope forms vary in some measure. In brief, the overall profiles are not smooth but gently concave curves with planar and concave segments. In most profiles, the upper regions are slightly steeper and more concave than the middle and distant segments. The degree of concavity varies among the fans.

The breaks in slope in the longitudinal profile demarcate the different fan segments. The angular relation between any two adjacent straight segments is indicated by extending the trace of the lower segment upslope. Vertical exaggeration is necessary in drawing the profiles to show clearly the segmented shape of the radial profiles. Vertical exaggeration in the profiles of the Rakti and Rohini is ten times, whereas in the Mahanadi fan it is 20 times.

Based on the breaks in slopes, the fan surfaces under study can be distinguished into three broad zones and each of these zones has its own individual characteristics.

1) Upper fan or fan head
2) Middle fan
3) Lower fan or fan base

Upper fan segment

The upper fan segment of the Rakti and Rohini is confined within the contour limits of 320mt. in the east and the west, but the lower limit goes down to 260mt. in case of the central fan. The slope of the east and the west fans generally varies from 3.5 degree to 5 degree, while the slope has been accentuated on the central fan to about 10 degree by the accumulation of the debris flow materials. Seepage along this steep slope has given rise to parallel first order streams. The deposits of the upper fan are generally dominated by coarse gravels, cobbles and boulders. Such areas are under constant modification due to intermittent stream action, flash flood and mass movements. Due to stream action the fan heads are deeply entrenched. Huge flash flood debris and mass movement materials are found scattered over the surface.

The Mahanadi fan in contrast, is much gentler in slope and larger in size. The upper fan segment is confined within the 180m contour between the Mahanadi and the Panchanai nadi, but beyond the Panchanai nadi to the west, this zone is limited within the 220 mt. contour. The slope varies between 3 degree and 6 degrees within this zone. Here the deposits are dominated by coarse gravels and cobbles but boulders are absent in this zone. However fan heads in this zone are not deeply entrenched, and the river bed has broadened abruptly upon its entrance onto the planes near Sukna.

Middle fan segment

This segment extends between 320mt. contour in the north and the 200mt. contour in the south in its western and eastern parts. In the central part it extends between 260mt. contour in the north and 200mt. contour in the south. The general slope varies between 1.5- 3 degree. The presence of boulders are quite uncommon here, except occasionally in the river banks. The soils are mostly sandy and silty. Being away from the apex, this zone is rarely affected by the hazards of flash floods and mass movements, but stream action is quite competent in producing steep scarps of 15-25 mt. bordering the rivers. Stream floods often affect the lower part of the segment.

In the Mahanadi fan, the middle fan segment is confined within the 160 mt. contour in the south and the slopes vary within 1.5 and 3 degree. Medium grained sand and silt are prevalent here. Stream action and stream floods are the prominent processors. Here also the lower parts are often affected by floods.

Lower fan segment

Beyond the 200mt. contour is the zone of coalescence where the lower fan segments are the Rakti and Rohini fans coalesced due to frequent flooding of the existing braided streams and the mingling of their flood water together with flood deposits. Here the deposits are mainly fine grained sand, silt and clay. The overall slope varies between less than 1 degree and 1.5 degree. The rivers often change their courses during floods. Bank erosion producing scarps of 5-10mt. height is common, especially along the Balasan.

Beyond the 160mt. contour in the Mahanadi fan, lower fan begins which further down grades into the flood plane area. The slope is very low here and the soil is dominantly fine grained sand, silt and clay. Stream action and stream floods are the most prominent processes prevalent in this zone.

The cross profiles drawn across the fan area are convex in nature. The central parts of the fans are generally higher than the sides because of greater deposition on the central part. The convexity decreases towards the lower fan area (Fig. II.5).

PROCESSES OF DEPOSITION

During the Pleistocene period when the higher parts of the Darjeeling Himalayas were experiencing wide spread glaciation, the lower reaches of the Himalayas was subjected to periglacial conditions. During this period, the main streams coming out of the hills along with their tributaries brought down a great

# Cross profiles across the Mahanadi-Balasan interfluve alluvial fans

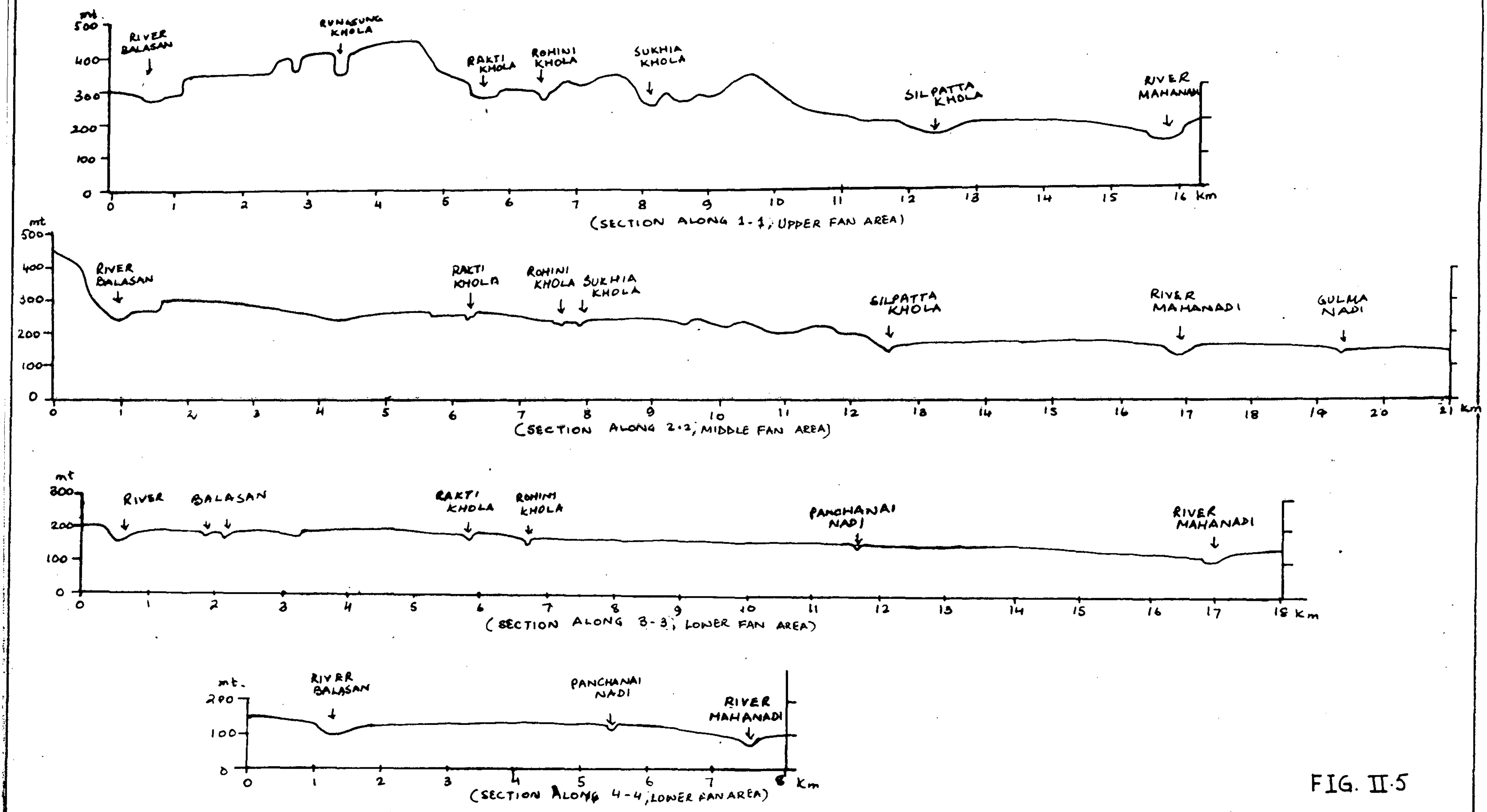



FIG. II·5

volume of periglacial debris and solifluction material which eventually were deposited as coalescing alluvial fans at their outlets (Kar, 1962, 1969). Later fresh coarse pebbly sediments were deposited by debris flow near the fan apex and the medium sand stones and silt stones were deposited as braided stream deposits near the fan base. The streams like the Rakti and Rohini, which are very deeply entrenched near the fan head area can hardly supply sediment to the fan surface in the upper reaches of the fan. Here the fans are very steep in nature indicating the dominance of debris flow as the main process operating here that bring large boulders on the fan surface. The boulders present on the stream beds are either brought down by the streams during period of heavy rainfall or are incorporated from the scarp face due to under cutting by the stream. The boulders lying on the bed of the Balasan are probably brought down by the river itself. Boulders are lacking in the channel of the Mahanadi and the adjoining fan surface.

## LAND FACET MAP

A land facet map (Fig. II.6) has been prepared for the study area to identify the different facets of landform. The correlation of the different facets gives an insight into the environmental conditions that prevail in the area. The six main facets as seen in the study area are:

1) Foothill region
2) River bed
3) River bank
4) Escarpment
5) Interfluve
6) Mounds

The foothills region in the north rise abruptly from the undulating Terai plains, showing a sharp break in the profile. The river channels, flowing in deep winding courses through the mountainous region, spread out upon their entry onto the Terai plains, forming braided channels. The riverbeds on the alluvial fan area have two types of deposition. River islands are those deposition on the riverbeds that are vegetated and are thus permanent in nature. Cultivation is carried out on a

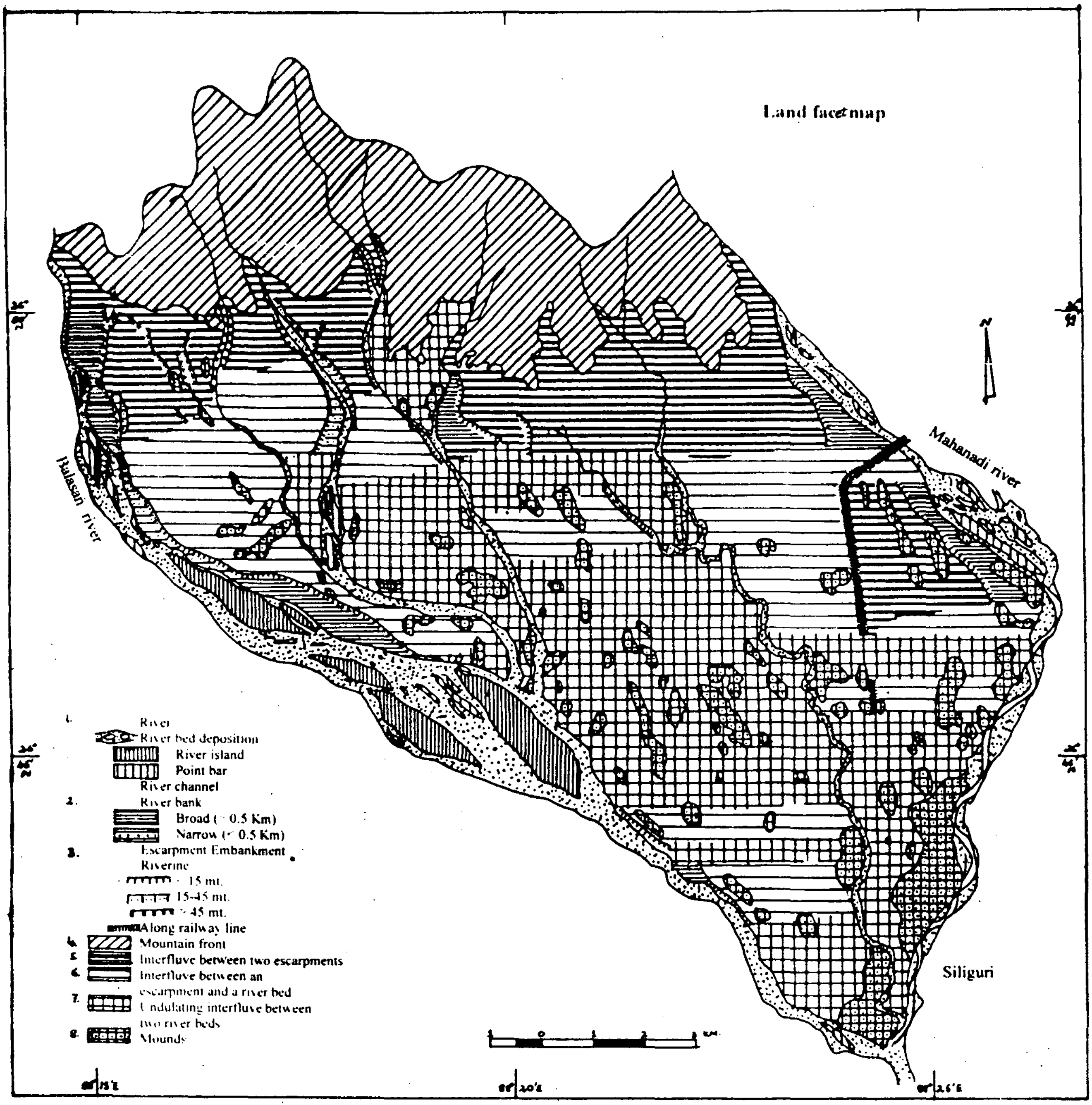

Land facet map
Mahanadi river
Balasan river
Siliguri
N
1. River
River bed deposition
River island
Point bar
River channel
2. River bank
Broad (> 0.5 Km)
Narrow (< 0.5 Km)
3. Escarpment Embankment
Riverine
< 15 mt.
15-45 mt.
> 45 mt.
Along railway line
4. Mountain front
5. Interfluve between two escarpments
6. Interfluve between an escarpment and a river bed
7. Undulating interfluve between two river beds
8. Mounds

Fig. II.6

regular basis and some parts of these river islands are also forested. The second type of riverbed deposition, point bars, are not vegetated and they get inundated during periods of high floods. During dry months when the discharge of the rivers are very low, the water flows through a narrow channel only.

The river banks in the entire study area can be classified into two broad categories

1) Broad (> 0.5 Km. wide) and 2) Narrow (< 0.5 Km. wide). The Mahanadi River does not have such river banks as can be seen beside the Balasan and the Rakti Khola. The banks beside Balasan are broad in the north near Longview tea garden, and in the south before its confluence with the Rakti Khola. Beside Marionbari tea garden in the central part, the banks are narrow and the entire area is covered by dense mixed jungle. The banks beside the Rakti Khola in the north are narrow. The banks are bound by escarpment, their heights varying between 2 and 65 mt. These escarpments were formed by rapid down cutting by the rivers upon their entry on the alluvial fans during their formative period. The heights of escarpments in the upper fan area are much greater than in the lower fan areas, where the heights of the escarpments vary between 3 and 12mt. Where the escarpments lie away from the river channels, it indicates former channels of the rivers. Due to river migration, such escarpments now lie away from the present channels.

The interfluve region of the study area can be divided into three subdivisions:

1) Interfluve between escarpments, 2) Interfluve between an escarpment and a river bed, and 3) Undulating interfluve between two river beds. The first two types of interfluve region can usually be seen in the upper and middle fan areas. Due to the great heights of the escarpments these areas never get inundated during high floods. However, flood water often inundates interfluves between two river beds. In the lower fan areas, absence of escarpments lead to inundation of the low lying areas. The mounds representing settled areas hardly ever get inundated, except in cases of very

high floods. Due to frequent floods in the lower parts of the study area the rivers often change their courses. Thus, geomorphologically the lower parts of the study area are more susceptible to change. The higher parts of the foot hills and the upper fan areas are more prone to erosion due to steep slopes and less vegetation cover at places. The sediments thus eroded are carried downslopes by the rivers, depositing them in the lower parts and changing the overall configuration of the lower fan areas.

The Balasan-Mahanadi interfluve area is formed by coalescence of alluvial fans formed by the main rivers and their tributaries flowing through the area. The morphological characteristics of the area conform to those of alluvial fans. The fan building processes in the form of flash floods and debris flows are prominent in the upper fan areas and the lower fan areas are being modified constantly by human activities showing the dynamic nature of the fans.

# CHAPTER III

## RAINFALL CHARACTERISTICS

The Balasan-Mahanadi interfluve fan area is situated at the base of the high Darjeeling Himalayas and is a part of the vast Terai-Duars plains. The entire district is affected by the south-west monsoon during the months from June to October and the marked orography plays an important role in modifying the rainfall distribution. The south west monsoon normally sets in over this region in the first week of June and withdraws from there in the second week of October. Almost 80% of the annual rainfall occurs during the months June to September. Rainfall is also significant in the months of May and October, accounting for about 10 and 15% respectively of the total annual rainfall. This fact can be seen from the following table, showing the average monthly and annual normal rainfall and number of rainy days over the entire North Bengal.

Table 3.1: Average monthly and annual normal rainfall (mm) and number of rainy days over North Bengal.

| Months | Normal Rainfall (mm) | Monthly rainfall as % of annual | Normal no. of rainy days | Rainfall/rainy day (mm) |
|---|---|---|---|---|
| January | 10.7 | 0 | 0.9 | 11.9 |
| February | 23.6 | 1 | 2.1 | 11.2 |
| March | 43.2 | 1 | 2.9 | 14.9 |
| April | 133.0 | 4 | 7.5 | 17.7 |
| May | 339.8 | 10 | 14.7 | 23.1 |
| June | 734.3 | 21 | 19.8 | 37.1 |
| July | 791.2 | 23 | 21.5 | 36.8 |
| August | 653.3 | 19 | 20.2 | 32.3 |
| September | 531.6 | 15 | 16.5 | 32.2 |
| October | 159.5 | 5 | 5.9 | 27.0 |
| November | 17.1 | 1 | 1.0 | 17.1 |
| December | 5.4 | 0 | 0.5 | 10.0 |
| Annual | 3442.7 | | 113.5 | |

Source : Abbi et al , 1970

It is evident from the table that 21 and 23 % of the normal annual rainfall occur in the months of June and July respectively, with August and September accounting for 19 and 155 respectively. These four months together account for about 69% of the total number of rainy days over the entire North Bengal. The amount of rainfall per rainy day is also very high during these four months with an average rainfall of 34.6 mm per day(the rainfall amount varying between 37.1 mm in June to 32.2 mm in September). However, rainfall amounts and the number of rainy days are also comparatively high in months of May and October. The region receive 339.8 mm of rainfall on an average over 14.7 days (with 23.1 mm rainfall per day) in May and 159.5 mm of rainfall over 5.9 days (with 27.0 mm of rainfall per day). Thus, the months from May to October receive about 80% of the total precipitation occurring over the entire North Bengal districts. Thus, comparatively large number of rainy days and higher values of rainfall in June to September show that the rainstorms of moderate to severe nature persisting for several days are more likely to occur in these months than in other months. However, a smaller number of rainy days in October with almost the same amount of rainfall per day as that in August and September implies the possibility of rainstorms of comparatively smaller duration but of severe nature occurring in this month. Pre monsoon showers account for the moderately high amount of rainfall per day(23.1 mm) in moderately high number of rainy days in May. The months from November to April are quite dry experiencing very small amount of rainfall in a very few number of days. Thus, the months from May to October forms the wet period, while the dry period is experience from November to April.

CAUSES OF RAINFALL IN DIFFERENT SEASONS

North Bengal is susceptible to heavy and persistent rainfall during the monsoon season. In addition, rainstorms are quite normal during this season as can be seen from the following statistics showing the distribution of rainstorms over this period.

Table 3.2: Average occurrences of rainstorms(1901-1968)

| Months | May | June | July | August | September | October | Total |
|---|---|---|---|---|---|---|---|
| No. of rainstorms | 1 | 25 | 35 | 11 | 10 | 3 | 85 |

Source: Abbi et al , 1970

Almost 70 % of the rainstorms over North Bengal occur in June and July and only 3 rainstorms have occurred in October during the period 1901-1968. The rainstorms causing heavy rainfall even during the monsoon months occur due to one of the following reasons.

1. Break monsoon conditions, i.e. shifting of the axis of the monsoon trough close to the foot of the Himalayas:
2. Movement of the eastern end of the monsoon trough to the north of its normal position:
3. Depressions/storms originating over the Bay of Bengal and having their track either to east or west of North Bengal:
4. Depressions/storms originating over the Bay of Bengal and moving in a northerly direction through the area under study: and
5. Low pressure systems lying over/near the region.

## ANNUAL RAINFALL AND MONTHLY DISTRIBUTION

The annual rainfall over the study area varies between 3448.6 mm at Siliguri and 4280.9 mm at Longview tea garden.

Table 3.3: Mean monthly precipitation (mm)

| Months | Sukna RS (1970-86) (mm) | Gulma TG (1971-86) (mm) | Salbari (1971-86) (mm) | Siliguri (1901-61; 1973-78) (mm) | Longview (1968-86) (mm) | Pankhabari (1942-51; 1971-86) (mm) |
|---|---|---|---|---|---|---|
| January | 1.3 | 20.0 | 15.1 | 9.1 | 33.2 | 18.7 |
| February | 2.0 | 14.0 | 24.6 | 15.1 | 35.2 | 20.2 |
| March | 2.0 | 35.1 | 39.9 | 30.3 | 68.8 | 30.8 |
| April | 110.0 | 83.0 | 79.0 | 95.6 | 69.2 | 107.8 |
| May | 218.0 | 211.0 | 312.6 | 283.3 | 196.6 | 206.8 |
| June | 730.0 | 730.0 | 622.0 | 715.1 | 937.1 | 730.9 |
| July | 910.1 | 910.0 | 1070.0 | 822.3 | 1239.3 | 906.9 |
| August | 760.2 | 760.0 | 553.0 | 725.2 | 898.9 | 784.1 |
| September | 982.0 | 982.1 | 593.0 | 558.4 | 592.8 | 540.2 |
| October | 105.0 | 105.0 | 185.0 | 164.0 | 156.6 | 136.0 |
| November | 130.0 | 130.0 | 11.2 | 19.8 | 33.7 | 23.7 |
| December | 4.0 | 4.0 | 8.0 | 10.4 | 19.5 | 6.3 |
| Annual | 3954.6 | 3984.2 | 3513.4 | 3448.6 | 4280.9 | 3512.4 |

For detailed study, Siliguri has been taken as the representative station for the area as the data is available for the maximum number of years (1901-61 and 1973-78). The average annual rainfall at the station Siliguri, which has been taken as the representative station of the study area, experiences 3448.56 mm of rainfall on an average. The rainfall varies over the years with a CV of 26.70 %. The maximum annual rainfall experienced at this station was in 1926 when 5080.00 mm of rainfall occurred over the year with the months June, July and August experiencing very heavy rainfall at an average of 1208.23 mm per month. The winter months from November to February remained almost dry. The years 1928 and 1974 also experience moderately high rainfall of over 4660.00 mm. In 1974, the months July and August experienced very heavy rainfall of 1426.00 mm and 1072.00 mm respectively. The other monsoon months received moderate amount of rainfall, and the winter months remained almost dry. The seasonal distribution of rainfall can be understood from the following table.

Table 3.4: Monthly distribution of rainfall (mm)

Station: Siliguri

| Months | Mean (mm) | SD | CV(%) | Months (mm) | Mean | SD | CV(%) |
|---|---|---|---|---|---|---|---|
| Jan | 9.08 | 16.33 | 182.11 | Aug | 725.24 | 295.43 | 40.74 |
| Feb | 15.12 | 20.37 | 134.70 | Sep | 558.40 | 241.15 | 43.19 |
| Mar | 30.27 | 30.97 | 102.29 | Oct | 164.04 | 122.97 | 74.96 |
| Apr | 95.55 | 73.39 | 76.81 | Nov | 19.77 | 43.84 | 221.79 |
| May | 283.27 | 140.79 | 49.70 | Dec | 10.38 | 53.16 | 512.33 |
| Jun | 715.06 | 229.42 | 32.08 | | | | |
| Jul | 822.28 | 320.67 | 39.00 | Annual | 3448.46 | 920.71 | 26.70 |

The maximum amount of rainfall is concentrated in months May to October with almost 95% of rainfall occurring during this period. The months from November to March experience very low amount of rainfall. Thus, the winter months remain quite dry. Some amount of rainfall occurs in the month of April, which may be attributed to pre-monsoon showers and local depressions.

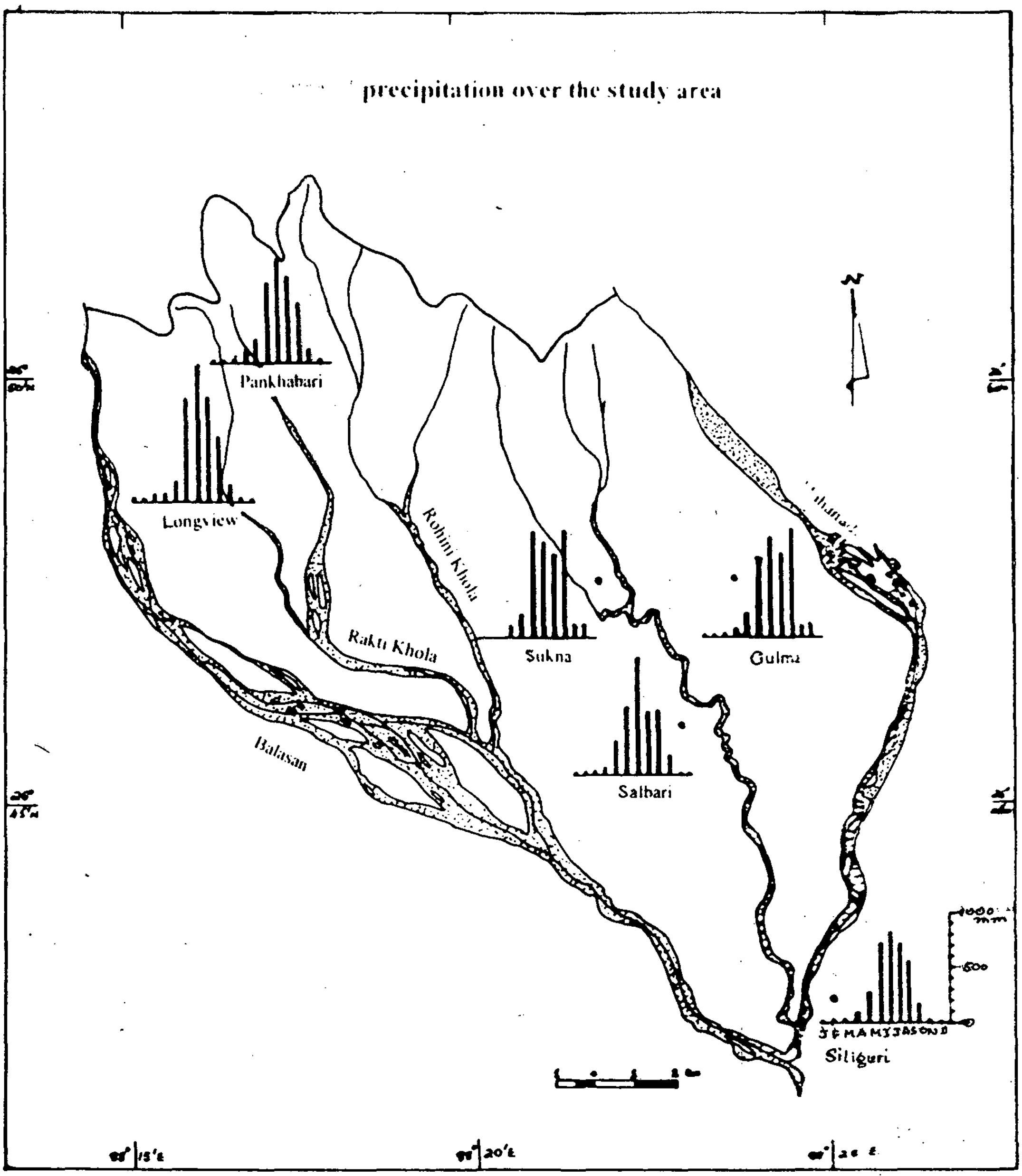

precipitation over the study area
Pankhabari
Longview
Rohini Khola
Rakti Khola
Balasan
Sukna
Gulma
Salbari
Siliguri
500
J F M A M J J A S O N D

Fig.III.1

It can be seen that the coefficient of variability of monthly rainfall at Siliguri varies between 32.1 and 49.7 for the months May to September. Thus the monthly rainfall for these months do not vary much over the years and the rainfall features of these months are repeated year after year. However, the coefficient of variability for the month of October (75.0%), indicating that in this month low amounts of rainfall are recorded comparatively in a larger number of years with markedly high amount s in a few years. The high variability of October rainfall further confirms the possibility of occurrence of severe storms in this month although their frequency may be very low.

## SEASONAL RAINFALL IN THE STUDY AREA

Four seasons are prominently experienced all over the North Bengal area. Summer prevails during the months of March to May after which monsoon arrives and the months from June to September experience the heaviest rainfall from the south west monsoon. The season of retreating monsoon is during the months of October and November, and December to February is the coldest period experience in this area. The amount of rainfall received during each of these seasons can be understood from the following table.

Table 3.5: Seasonal rainfall (mm)

Station : Siliguri

| Season | Duration | Avg. Rainfall (mm) | SD | CV(%) |
|---|---|---|---|---|
| Summer | Mar-May | 340.91 | 221.90 | 65.09 |
| Monsoon | Jun-Sep | 2350.82 | 1232.80 | 52.44 |
| Ret. Monsoon | Oct-Nov | 153.17 | 138.02 | 90.11 |
| Winter | Dec-Feb | 28.81 | 53.34 | 185.14 |

The maximum average rainfall occur during the monsoon period of May-September (2350.82 mm/month on an average). More than 80% of the total annual rainfall occur during this period. The summer months (March –May) also have moderately high rainfall of 340.91mm/ month on an average due to the fact that the month of May experiences moderately high rainfall from occasional rainstorms and from pre-monsoon showers. Rainfall during the season of retreating monsoon is mainly from occurrence of rainstorms and the very little rainfall that occurs during the winter months are from western disturbances in the form of rain in the plains and snow in the higher reaches of the Darjeeling Himalayas.

Coefficient of variability remains quite low in the summer and monsoon seasons indicating very less variation in rainfall during these two seasons. However, CV increases to 90.11% in the season of retreating monsoon showing moderate variability of rainfall. During the winter seasons, the CV of rainfall is as high as 185.14 %, indicating very wide variation of rainfall over the years.

DAILY RAINFALL INTENSITY OVER THE STUDY AREA.

The amount of rainfall per rainy day gives the 24 hour intensity of rainfall, that to some extent help in understanding the role of rainfall in causing soil erosion. The heaviest 24 hour rainfall amounts (recorded upto 1960) experienced at the station Siliguri is 322.6 mm on 24.6.1957. The month of June that year also received very high rainfall of 1040.90 mm . The study of intensity of rainfall is very important for assessing the status of soil erosion in an area. The higher the rain intensity, the greater will be the amount of soil erosion. The mean intensity of rainfall over the years at the station Siliguri remains very high during the months June to September, experiencing on an average over 30mm of rainfall per day. Rainfall intensity in June (30.61 mm per day), July (36.14 mm per day), August ( 33.60 mm per day) and September ( 32.27 mm per day) being very high during these months result in great volume of soil erosion. The intensity of rainfall remains moderately high in April (134.8 mm per day), May (20.1mm per day), October (25.3 per day) and in November (22.81 mm per day). The intensity in April and May are significant because soil is more prone to erosion at this period due to lack of vegetation cover at the end of summer.

HEAVIEST STORM EXPERIENCED

The rainstorms of 11-13 June 1950 and 3-5 October 1968 were of very high magnitude. The rainstorm of 11-13 June 1950, occurred in association with the cyclonic storm initially formed over the Bay of Bengal. It travelled northwards and broke up over the North Bengal hills by 12th evening, causing heavy rainfall over the entire North Bengal. Several places recorded the heaviest 24-hour rainfall during the period upto 1960 in this heavy spell of rainfall. This caused severe landslides in Darjeeling, Kalimpong, Kurseong and the adjoining areas.

The 3-5 October 1968 rainstorm was also cause in association with a Bay depression. The storm broke over North Bengal by 5th evening. Very heavy and widespread rains occurred over North Bengal from 3-5 October, 1968. The highest 24-hour rainfall recorded upto 1960 in North Bengal hills have been exceeded during this period. Continuous heavy rains over hills of North Bengal resulted in landslides and devastating floods in this region. The districts of Darjeeling, Jalpaiguri and Cooch Bihar were worst affected by floods.

Such detailed study on rainfall over the study area is necessary in order to know the role of rainfall in eroding the soil of the region. Rainfall is the single most important factor causing soil erosion being modified by the other factors of slope of the land, soil characteristics and vegetation cover over the area. Thus, in order to carry out a detailed study on soil erosion on Balasan-Mahanadi interfluve fan area it is necessary to understand the rainfall conditions including total rainfall, intensity of rain and seasonal variation prevailing over the area.

# CHAPTER IV

# SOIL AND SOIL EROSION IN BALASAN-MAHANADI INTERFLUVE ALLUVIAL FANS

Soil has been defined as a "natural body of mineral and organic constituents differentiated into horizons at various depths which differ from the material below in morphology, physical make up, chemical properties, composition and biological characteristics". The alluvial fans composing the pediment plain in North Bengal are apparently of fluvial origin. From the geological point of view the soils of North Bengal are mainly the products of weathering of fluvial clastics and they have developed on the Quarternary deposits of the piedmont plain along the southern flank of the Himalayas. The fan area of this region exhibits a diversity of sediment and soil colour.

The sediments of the fan areas of North Bengal are of transported origin with heterogeneous parent material in which the uppermost A horizon is made up of finer material while the material underlying it is a pebble-gravel and boulder horizon, which is therefore, of lighter texture and greater porosity. Also rapid decay of organic matter in humid tropics leads to only minor clay content in the A horizon, thereby inhibiting the formation of organic colloids which could lead to the formation of an impervious layer. Moreover, very low ground water conditions contribute to the free access of percolating waters to great depths leading to the formation of very deep weathering profiles. Thus, with time a greater depth of oxidation and solution is achieved, resulting in the orange and later red coloured sediments.

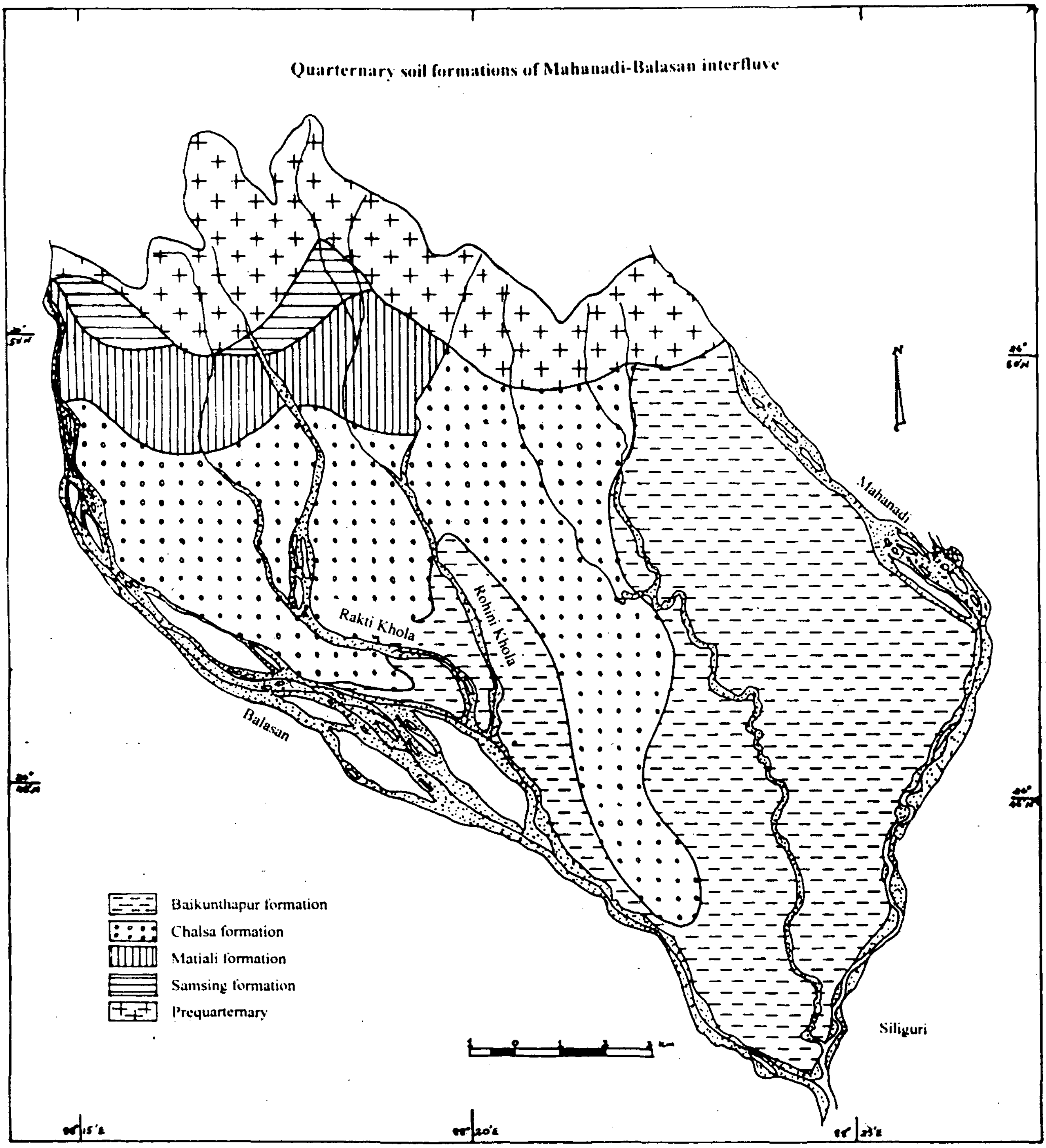
The colour of a soil horizon is a product of the processes of soil developments (Das and Chattapadhyay, 1988). The thickness and maturity of the soil zone tends to increase with time and with the accumulation of vegetal matter and continuous weathering of the parental rock material. Thus, the level of oxidation can be utilised for classification of sediments in relation to time sequence.

The first unit or the Shaugaon formation with no soil cover is the youngest horizon, which is absent within the study area. The sediment is fresh, unoxidised and grayish white in colour. These deposits flank the present day flood plains and as soil takes time to develop, its absence indicates that the deposits is quite recent in origin.

The second unit, the Baikunthapur formation, which is next in order of antiquity, has a well developed black soil horizon, having organic matter content, overlying generally unoxidised weathering zone and is widely found in the Balasan basin between the rivers Balasan and Mahanadi near Siliguri (Fig. IV.1). The sediments mainly consist of coarse to fine sand grading southwards, away from the foothills, to silt and clay. Where it has not been eroded away, a veneer of 4 cm to 1 mt. thick dark grayish black soil horizon containing organic matter is observed on the top of the deposit which is composed mainly of sand.

The third unit, the Chalsa formation ranges from boulder to sand size fractions and consist of brown top soil overlying a yellow weathering zone. The yellow colour of the weathering zone is due to the presence of iron hydroxides and the brown colour of the soil is due to the combination of the yellow of the hydroxides and black of organic compounds. Very often, the brown soil zone made up of sand to silt sized material is found to overlie the yellow pebble-cobble-boulder horizon or the weathering zone. As the material is pervious, the air and water action affects the whole of lower horizon and weathering effect is more in this horizon. This soil layer ranges from a few centimeters to over one meter and is generally thinner at the slopes.

The fourth unit or the Matiali formation ranges from boulder to sand size fractions. It consists of an orange to red weathering zone overlain by reddish brown top soil. The sandy matrix of this pebble-cobble-boulder horizon is orange to red in colour due to greater presence of iron oxides relative to hydroxides. The reddish brown top soil is made up of smaller silt sized fraction and the soil colour



Quarternary soil formations of Mahanadi-Balasan interfluve
Mahanadi
Rakti Khola
Kohini Khola
Balasan
Siliguri
Baikunthapur formation
Chalsa formation
Matiali formation
Samsing formation
Prequarternary


Fig. IV.1

is a combination of the orange colour of the weathering zone with the black of organic compounds.

The fifth unit, i.e. the Samsing formation is generally made up of boulder of various sizes, some of which are over 2 mt. in diameter with little or no matrix. The top soil layer is over 1.5 centimeter thick and chocolate brown in colour, the colour being a combination of red and black. Red is the colour of sediments that have reached the ultimate state of oxidation and black is the colour of organic compounds.

## RELATION BETWEEN TOPOGRAPHY, DRAINAGE AND SOIL

The stratigraphy and nature of the fan sediments in the Balasan –Mahanadi interfluve area reflects the relationship between the general topography, the climatic conditions that are prevailing, the drainage characteristics and the transporting capacity of the channels and the modes of deposition of the fan sediments.

As is evident from the soil map of the area, the Mahanadi fan is mainly composed of the youngest sediment found in the area- the Baikunthapur formation. This sediment mainly consists of coarse to fine sand particles, and boulders are generally absent in this area. This fact indicates that the sediments are mainly river borne and are more recent in origin than the soils found in other parts of the interfluve area. Absence of boulders even in the upper fan areas indicate that stream action and stream floods are mainly responsible for the development of the fan and flash flood and debris flow hardly contribute any sediment in the process of fan building. The River Mahanadi, often overflow its banks and contribute fresh sediment to the fan surface. Landslides, which are a common occurrence in the mountainous parts, also contribute sediment through jhoras and nullahs that join the main channel of Mahanadi.

The Balasan-Rakti-Rohini sector shows more varied range of soil types than in the Mahanadi sector. The sediments older than the Baikunthapur formation- Chalsa, Matiali and Samsing are all found in the fans created by these rivers. Here the younger Baikunthapur formation is found only in the extreme south where the Rakti and Rohini meets the River Balasan, the slopes here are very gentle and the topography flat. This part of the fan only receives fresh sediments from the streams. In the fan head area in this sector the oldest Samsing formation is found which is generally made up of boulders of various sizes with little or no matrix. The very thin layer of top soil, which is chocolate brown in colour is a combination of highly oxidised sediments and organic compounds. The prevalence of boulders indicate the dominance of flash floods and debris flow as the main fan building process. The slope of the land are quite steep (3.5 degree to 10 degree) and the topography in general are undulating.

The middle fan area, having lesser slope of 1.5 t0 3.5 degrees and more or less flat topography, covered by Matiali formation consists of moderate to highly oxidised soil zones, with predominance of sand particles. The level of oxidation indicates high level of soil formation which is only possible when there is no inundation of the soil due to floods. Here the sediments are usually transported from the upper parts of the fans. Thus, the size of the boulders present in the area are smaller and particle size range from boulder to sand size fractions. Here river action has no contribution in fan building as the channels are all deeply entrenched into the fan surface. Thus, whatever transportation is done by the rivers is in the down fan direction, resulting in the decrease of particle size.

The lower middle and the lower fan areas covered by the Chalsa formation ranging from boulder to sand size fraction. The material in this zone is pervious and is more perceptible to weathering. This zone is also not affected by floods. The zone covered by Biakunthapur formation lying to the south of this zone sometimes get fresh sediments from the rivers.

Thus, the modes of sediment deposition in the entire study area somewhat controls the topography of the area also. The Balasan-Rakti-Rohini sector that are more affected by fresh floods and debris flow have steeper slopes and more undulating topography, whereas the Mahanadi sector affected mostly by stream action and stream floods have much gentler and smoother topography.

The upper and middle fan segments experience more actively the process of leaching of soil nutrients than in the lower fan segments as the former zones have better vegetal cover, moderate slopes and receives comparatively higher rainfall. Thus, the finer particles of clay and silt move downward leaving a silica dominated coarse textured surface soil. Thus, a B-horizon develops at depths of 10-60 cm below the surface in the upper and middle fan zones where clay and silt content is more (Basu and Sarkar, 1990). However, such profile development is absent in the lower fan areas due to continuous use of the land for agriculture. This zone also gets fresh sediments, mostly sands, through intermittent flooding, and overall deforestation in this segment hinder profile development. In the Mahanadi sector, however, the middle fan area is also subjected to agricultural practices to some extent, resulting in disturbances in the soil forming process.

The presence of deciduous forest with considerable undergrowth in the upper and middle fan segments of the Balasan-Rakti-Rohini sector and in the upper fan segment of the Mahanadi sector, accumulation of organic matter in the soil is higher by 2-3% than in the lower fan areas, where lack of forest cover help very little in adding organic matter to the soil. The continuous use of the deforested tracts for settlement and agriculture is a limiting factor for the accumulation of organic matter in the subsurface soils in the lower fan area, there by hindering the formation of a well defined B-horizon.

Land use in these fan areas are changing rapidly due to increasing pressure of population on land. More and more land are being converted to agricultural land. Constant tillage of such agricultural land lead to increased soil erosion. Different types of fertilizers are also being used by the farmers. But, fertilizer use as such does not increase erosion (Bockman et a, 1990). On the other hand, proper fertilizer use can help minimize erosion by ensuring an ample supply of roots and plant residues.

## SOIL EROSION

By soil erosion is meant the removal of surface material. There are two major climatic factors that cause soil erosion: wind (wind erosion) and water (water erosion). The study area being situated in humid tropics, is influenced totally by water erosion. Soil erosion is a normal aspect of landscape development. The physical phenomenon of erosion can be linked to two successive theoretical stages (Babau, 1983). One, disintegration of soil matter, which requires detachment of elementary particles of the soil mass, the compactness of which is determined by its mineral characteristics. This involves an initial form of energy, which is the kinetic energy of rainfall. Once separated form the mass the elementary particle requires another form of energy to carry it from one point to another. This second form of energy is runoff (force of gravity). Thus there are two forces at work:

- Kinetic energy, directly linked to the characteristics of the rainfall, and
- Runoff, similarly linked to the characteristics of rainfall and also to other factors such as slope, length of slope and "roughness", which involves the condition of the soil in broad sense, i.e., the plant cover, cultivation practices, etc.

Quantity of soil erosion is usually expressed in tonne/$Km^2$/year and is known as " specific erosion". Thus quantitative estimation of soil loss per year is necessary for formulating suitable conservation measures for restoring the maximum sustained productivity of soil for a given land use.

It has been observed in the study area, that the main erosional hazard of soil has been stemmed from the action of water. Other factors play rather minor role. The most widely used method of soil loss prediction is the Universal Soil Loss

Equation (USLE) by Wishmeier (1959), where estimation of erosion is done as a product of a series in terms of rainfall, slope gradient, slope length, soil and cropping factors, etc. Thus, the average annual soil loss of the area under study is evaluated as a multiplied function of the various factors like-

1) The rainfall erosivity factor (R)
2) The erodibility factor (K)
3) The topographic erosivity factor (L.S), where L = the slope length factor, and
   S = the slope gradient factor
4) The biotic factor (C.P) , where C = the cropping management factor and
   P = the erosion control practice factor

The first three factors, i.e., R, K, and L.S may be designated as physical factors as they estimate the potential loss or the natural vulnerability. The biotic factor (C.P) include the effect of vegetation cover, land use, human interference, etc. and thus gives an account of the loss resulting from the cultural environment. The combination of both the physical and cultural factors permit to estimate the actual or predicted soil loss.

In Wischmeier's Universal Soil Loss Equation , the physical processes of water erosion are influenced by six factors of which the rainfall erosive capacity is the dominant. The respective weights of each of these terms, according to Roose are –

R can vary from 1 to 1000

K can vary from 1 to 12

The product S.L can vary from 1 to 25

C can vary from 1 to 10

P can vary from 1 to 10

The influence of factor R overweighs that of the other. Consequently, the most rational way of identifying erosion prone areas is by studying factor R and by charting rainfall erosive capacity.

1. Rain Erosivity (R factor) of the study area

The rainfall erosivity factor in the USLE is the rainfall erosion index as presented by Wishmeier (1959). The R factor is a definition of the erosivity of rainfall events and is defined as the product of two rainstorm characteristics : kinetic energy (E) and the maximum 30-minute intensity ($I_{30}$). The product $EI_{30}$ is a measure of the manner in which energy and intensity are combined in a storm and defines the combined effect of raindrop impact and turbulence of runoff to transport soil particles from a field. The United States Department of Agriculture (USDA) has accepted $R= EI_{30}$ as a standard index of rain erosivity used in the USLE (Wischmeier and Smith, 1962). The rainfall erosivity factor R , is obtained by dividing the $EI_{30}$ product by 173.6 (Mitchell and Bubenzer,1980). This index predicts the soil loss due to sheet and rill erosion on the hill slopes and the result obtained by it is sufficiently reliable in most cases. However, this method has become almost unusable in country like ours where there is acute scarcity of data like 30-minute rainfall intensity from the rain gauge stations. Therefor, various other indices of rain erosivity have been proposed to substitute the R factor of USLE.

An index that requires little input of data and can be calculated effectively within the limitations on insufficient rainfall records is the Fournier's index (1972),

$R= Pm^2/P$,

where Pm is the average rainfall of the month with the highest precipitation (in mm) and P is the average annual precipitation. This index is very popular due to its simplicity, but a correlation study between the Fournier's index and $EI_{30}$ for 164 stations in USA and 14 stations in West Africa showed that the Fournire's index could hardly be used to approximate the R factor of the USLE (Arnoldous, 1980). The underlying philosophy of both the methods is different. In the USLE, all erosive rain increases the R value, while in the Fournier's index the month receiving the highest rainfall is the controlling factor.

The Fournier's index has been modified by the FAO/UNEP (1978) experts in such a way that not only the month that receives the highest rainfall but also the average monthly rainfall plays a critical role in the evaluation of the R factor. The equation is as follows:

$R = \sum p^2/P$

Where p is the monthly rainfall in mm, and

P is the annual rainfall in mm.

However, this index suffers from the shortcoming that only the total amount of rainfall plays an important role while another very important factor, rainfall intensity has not been considered at all.

To overcome this problem Sarkar (1989,1991) has developed an index in which the amount of rainfall as well as its intensity play important roles in the evaluation of the R factor, such as,

$R = \sum_{1}^{12} Pr^2_{10mm} /P$

Where, $Pr_{10mm}$ is the average monthly rainfall having > 10mm rainfall, and

P is the annual rainfall in mm.

However, in this equation the number of months having atleast 10 mm of rainfall has not been taken into account. Thus, this equation has been modified by Bhattacharyya (1993) in which the number of months having atleast 10mm rainfall has been taken into account and the equation stands as:

$R = \sum_{1}^{m} p^2_{\geq 10mm}/P$

Where, $p_{\geq 10mm}$ is the average monthly rainfall of the months having atleast 10mm of rain,

m is the number of months having $\geq$ 10mm rainfall, and

P is the mean annual rainfall in mm.

This equation has been used as an effective alternative of the existing standard index for the evaluation of rain erosivity, R. However, the accuracy of this index is to some extent provisional so long as the data of $EI_{30}$ index of the stations are made available for comparison. Thus, for calculating rain erosivity such equations should be adopted which consider the degree of intensity of rain at which soil erosion is possible. Months having more than 10 mm rainfall should only be considered for calculating R factor, as 10 mm rainfall is the minimum requirement for soil erosion to start.

Thus, in place of the existing standard index of rain erosivity, R= $EI_{30}$ used in USLE, the R index derived from the above mentioned equation has been taken as an alternative.

Table 4.1: rainfall erosivity factor (R)

| Station | p≥10 mm | P in mm | m | R |
|---|---|---|---|---|
| Sukna | 493.15 | 3954.60 | 8 | 491.98 |
| Gulma | 361.84 | 3984.20 | 11 | 361.47 |
| Salbari | 318.67 | 3513.40 | 11 | 317.95 |
| Siliguri | 312.68 | 3448.56 | 11 | 311.86 |
| Longview | 356.74 | 4280.90 | 12 | 356.74 |
| Pankhabari | 318.74 | 3512.40 | 11 | 318.16 |

Rain erosivity index, R is highest at the station Sukna, because the amount of rainfall capable of initiating soil erosion (≥ 10 mm) occur in 8 months of the year only. The rest of the 4 months have very less rainfall (< 10mm), incapable of initiating erosion. Also, the total amount of rainfall occurring within this 8 month period are much higher than in the other stations. Thus, erosion occurring within this span of 8 months at this station is much higher than in the other stations.

2) Soil Erodibility (K factor) of the study area

The soil erodibility can be expressed as the vulnerability of the soil to detachment and transport. The K factor in the USLE is a quantitative description of the inherent erodibility of a particular soil. The erodibility of soil is mainly estimated through the knowledge of particle size distribution of soil, i.e., its texture, the organic matter content, the structure and permeability. Therefore, estimation of K factor in the study area has been based on the following soil parameters:

1) The percentage of sand, silt and very fine sand
2) The organic matter content in percentage
3) The soil structure, and
4) The profile permeability

Each of these parameters affects erodibility of soil. Presence of very fine sand and silt in greater amounts bind the soil to some extent as the infiltration rate through this soil is slow because of the smaller size of the particles. Organic matter contents in greater amount also increase the compactness of the soil, making erosion less severe. Presence of greater amount of organic matter in the soil indicates the presence of vegetation over that soil that also hinders soil erosion. However, presence of more sand in soil means better infiltration capacity of the soil and the presence of lesser amount of fine silt, clay and organic matter. Thus, the compactness of the soil is less leading to greater degree of erosivity of the soil.

The estimation of soil erodibility factor (K) is based on the Soil Erodibility Nomograph of USLE (Wischmeier, Johnson and Cross , 1971, Fig. IV.2).

Table 4.2: Soil Erodibility Factor (K)

| Station | % very fine Sand & Silt | % sand | % Organic matter | Structure | Rate of permeability | K |
|---|---|---|---|---|---|---|
| Sukna | 16.74 | 43.15 | 2.93 | fine Granular | Slow to moderate | 0.12 |
| Gulma | 24.95 | 36.40 | 2.05 | fine Granular | Slow to moderate | 0.13 |
| Salbari | 32.51 | 42.76 | 0.89 | fine Granular | Slow to moderate | 0.19 |
| Siliguri | 3.24 | 92.01 | 0.31 | fine Granular | Moderate | 0.07 |
| Longview | 75.50 | 14.50 | 3.84 | Medium/ Coarse grained | Moderate to rapid | 0.33 |
| Pankhabari | 69.40 | 6.30 | 1.01 | Medium/ Coarse grained | Moderate to rapid | 0.43 |

## Soil erodibility nomograph

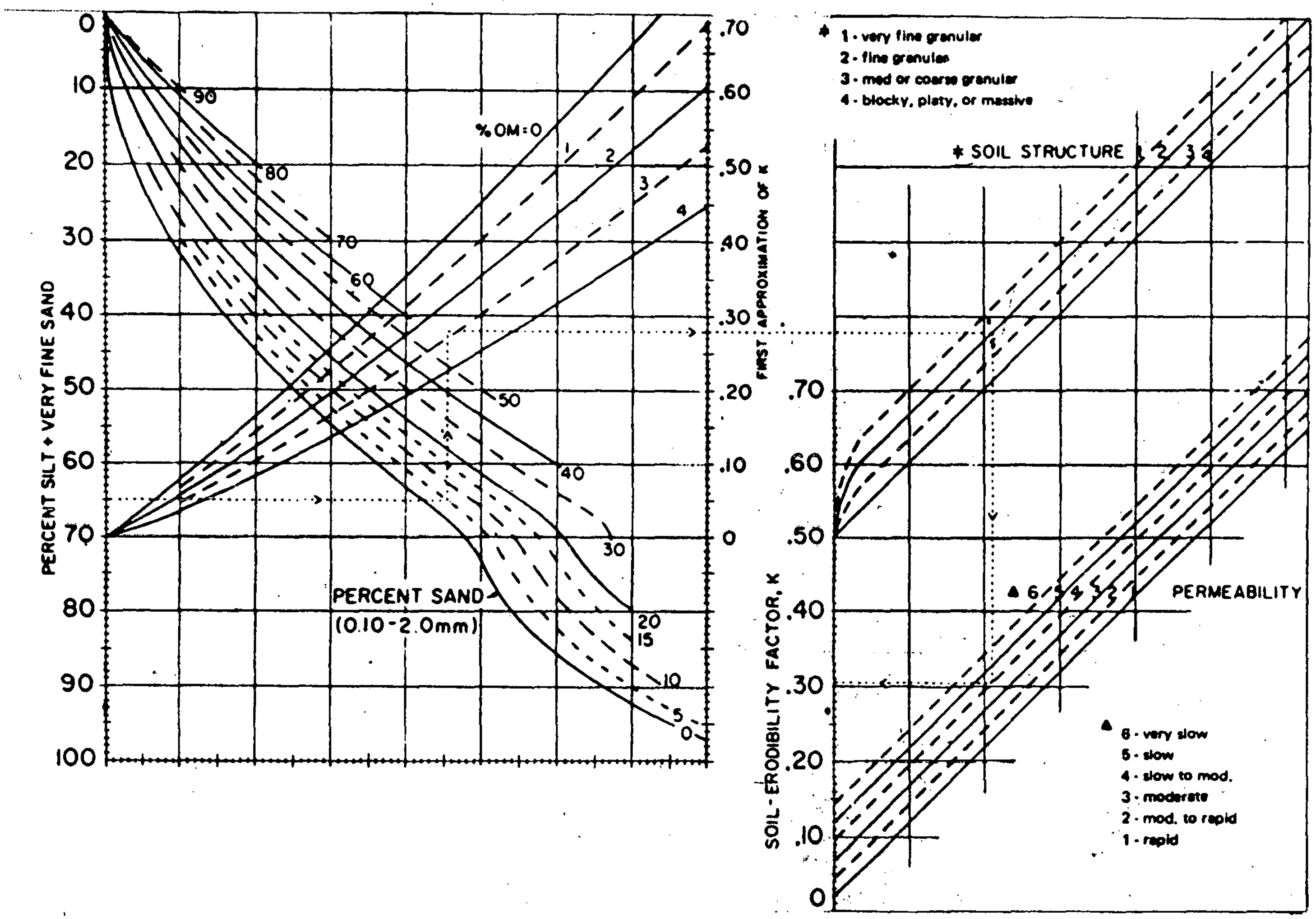



Fig IV.2

3) <u>Topographic Erosivity (L.S) factor of the study area</u>.

The effects of slope length and gradient are represented in the USLE as L and S respectively, but they are often evaluated as a single topographic factor, LS. The slope gradient and its length play a very important role for the assessment of soil erosion by water. Slope length is defined as the distance from the point of origin of overland flow to the point where the slope decreases sufficiently for deposition to occur or to the point where runoff enters a defined channel. The channel may be a part of a drainage network or a constructed channel. Slope gradient is the field or segment slope, usually expressed as percentage. For the determination of topographic erosivity of the study area, the percentage of slope gradient and its corresponding length have been measured at selected sites. Finally the index values of the LS factor has been obtained by employing the following empirical equation:

$$LS = \sqrt{L/100}\,(0.136 + 0.097s + 0.0139s^2)$$

Where, LS = topographic factor

L = Slope length in meters and

S = Gradient in percentage

The topogarphic erosivity has resulted from the different degrees of steepness. Therefore, higher LS factor is observed on the hill tract (Pankhabari) in comparison to the undulating Terai plains where the steepness of the land is much less. Thus, comparatively low topographic erosivity( <1 to > 4) is observed in the entire foothill region and its adjacent plains which gently slopes towards south. Although the topographic erosivity is a basic inventory for the assessment of the soil loss by water in a given area, but it does not play a critical role in the soil loss mechanism. Therefore, it is a very important subsidiary factor for the final assessment of soil erosion.

Table 4.3: Topographic erosivity factor (LS).

| Station | L(in meter) | S(in %) | LS |
|---|---|---|---|
| Sukna | 4750 | 1.20 | 1.88 |
| Gulma | 4500 | 0.88 | 1.56 |
| Salbari | 8000 | 0.50 | 1.68 |
| Siliguri | 4250 | 0.07 | 0.93 |
| Longview | 4750 | 3.37 | 4.28 |
| Pankhabari | 3015 | 16.58 | 30.56 |

4. Biological Erosivity (C.P factor) of the study area

Biological erosivity is a combination of the Cropping Management factor (C) and the erosion control practice factor (P). It can be explained as a combined functional effect of the type of land cover, land use and the soil management as well as the cultural practice which an area is experiencing. The evaluation of the C factor is often difficult because of the many cropping and management systems. The erosion control practice (P factor) usually includes contouring, contour strip cropping and terracing. Conservation tillage, crop rotations and fertility treatments and the retention of residues are important erosion control practices.

To determine he biological factors (CP) along with human interference of soil loss, it has been quantified depending on the assigned parametric rating values of each different types of land use. Since the land use types and patterns, ultimately depend on the complex physico-biological processes and it reflects the level of human interference in the natural ecosystem.

Biological erosivity (CP) at different sites has been determined from the available CP index, which also includes C and P coefficients of the USLE.

Table 4.4 :Rating table for the parametric values of CP factor

| Major land use type | Percentage coverage | Rating values |
|---|---|---|
| Natural vegetation cover, i.e. forest, bush, permanent pasture land | 80-100 | 0.05-0.001 |
| Tea garden | 80-100 | 0.09-0.05 |
| Degraded forests, rough grazing, perennial cover | 30-80 | 0.05-0.5 |
| Degraded tea garden | 30-80 | 0.09-0.5 |
| Row crops, intertilled crops | 30 | 0.5-0.8 |
| Terraced cultivated field | 20-50 | 0.5-0.8 |
| Root crops, such as ginger, potato, cardamom etc. | ±50 | 1.0-0.9 |
| Bare soils, cultivated fallow cover | 0 | 1.0 |

Source :FAO/UNEP (1978).

Table 4.5: Biological erosivity ( CP factor)

| Station | Land use | % Coverage | Rating Value |
|---|---|---|---|
| Sukna RS | Natural Veg. | 80 | 0.05 |
| Gulma TG | Tea garden | 80 | 0.09 |
| Salbari ARO | Cultivated | 60 | 0.85 |
| Siliguri | Bare soils | 0 | 1.0 |
| Longview | Tea garden | 52 | 0.15 |
| Pankhabari | Natural Veg. | 40 | 0.15 |

PREDICTED ANNUAL SOIL EROSION IN THE STUDY AREA

The predicted annual soil erosion can be expressed as the effective result of the vegetal cover as well as human interference on the potential erosional state of soil. Thus, predicted soil erosion is estimated by the following formula:

Predicted annual soil loss = R.K.LS.CP

Table 4.6: Predicted annual soil loss (tonnes/ha/yr)

| Station | R | K | LS | CP | Soil loss |
|---|---|---|---|---|---|
| Sukna | 491.98 | 0.12 | 1.88 | 0.05 | 5.55 |
| Gulma | 361.47 | 0.13 | 1.56 | 0.09 | 6.60 |
| Salbari | 317.95 | 0.19 | 1.68 | 0.85 | 86.27 |
| Siliguri | 311.86 | 0.07 | 0.93 | 1.0 | 20.30 |
| Longview | 356.74 | 0.33 | 4.28 | 0.15 | 75.58 |
| Pankhabari | 318.16 | 0.43 | 30.56 | 0.15 | 627.13 |

Highest soil erosion is noticed in the hilly tracts of north, where landslides are very common. This region has very steep slopes, with 40% of vegetation cover on the slopes. Soil erosion is moderate in the southern region. In Salbari and Longview tea garden area, about 50- 60 % area are cultivated, and the rest of the area are covered by settlements or by patches of bare soil. Thus, it promotes soil erosion to some extent. Siliguri consists of dense settlement cover with little or no vegetation cover, which also promotes moderate amount of soil erosion. Soil erosion is low in a small patch in the central part of the study area near Gulma tea garden and Sukna railway station. Soil erosion due to topographic factor is comparatively low in this region. Also, this region having 80% coverage of tea garden and natural vegetation, has low rate of soil erosion. Thus, the area can be divided into four zones of actual or predicted soil loss (Fig. IV.3).

i) Zone of very low actual soil loss (< 10 tonnes/ha/yr)

i) Zone of low actual soil loss ( 10-50 tonnes/ha/yr)

ii) Zone of medium actual soil loss (50-100 tonnes/ha/yr)

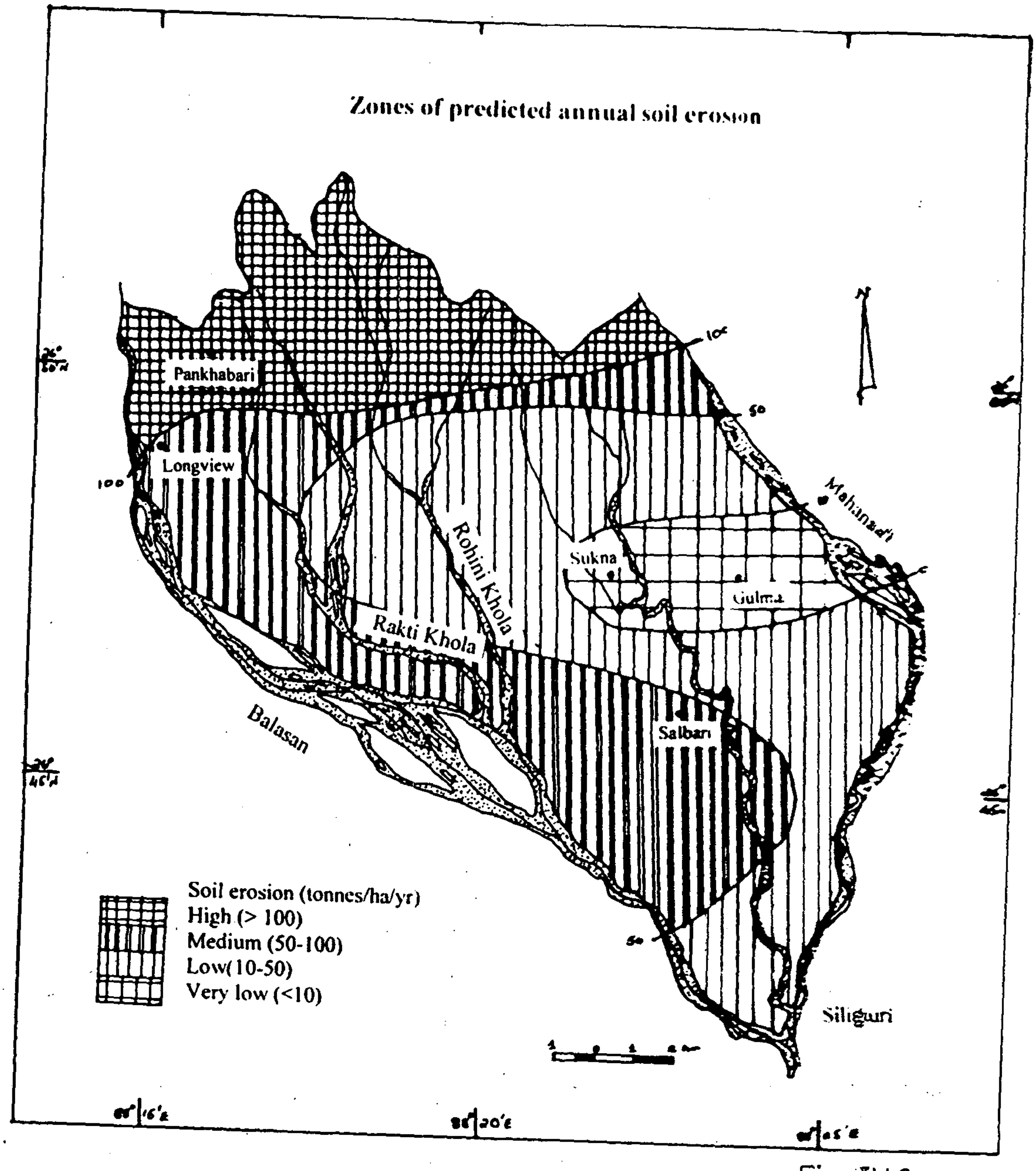

Zones of predicted annual soil erosion
Pankhabari
Longview
Rohini Khola
Rakti Khola
Balasan
Sukna
Gulma
Salbari
Mahanadi
Siliguri
Soil erosion (tonnes/ha/yr)
High (> 100)
Medium (50-100)
Low(10-50)
Very low (<10)

Fig. IV.3

iii) Zone of high actual soil loss ( > 100 tonnes/ ha/yr)

By analysing the pattern of soil erosion in the study area, it is found that rainfall has the maximum contribution in the initiation of soil erosion. Rain erosion being the most important in the study area, the region around Longview tea garden receiving the maximum amount of rainfall, has high rate of soil erosion. The mountainous region, although receive lesser amount of rainfall than the foothills, also has very high rate of soil erosion. This result from the soil characteristics of the area, which is prone to erosion, steep slope of the mountain front, and comparatively lesser amount of vegetation cover. This area around Pankhabari and along the Hill Cart Road, is prone to landslides due to unstable condition of the region which also leads to high rates of soil erosion.

Soil erosion is moderate in most of the plains below the foothill region due to moderate amount of rainfall, soils that are not so prone to erosion and moderate amount of vegetation cover or forested area or coverage by tea gardens. In this zone the topographic factor is less significant due to lack of steep slopes.

Soil erosion is very low in a small pocket in the central part of the study area around Sukna railway station and Gulma tea garden due to lack of steep slopes, soils that are less prone to erosion and very high percentage of coverage by tea gardens and forested lands. The Sukna railway station experience very high amount of soil erosivity as the effective rainfall of more than 10 mm that can cause soil erosion are concentrated in 8 months of the year only. Thus, the effectiveness of the rainfall in causing soil erosion is very high. However, the other factors of soil, slope and vegetation cover modify the effect of rainfall to a great extent at Sukna, resulting in the area having very low actual soil loss in a year per hectare area.

Thus, the overall soil erosion pattern of the study area show a combined effect of the rainfall characteristics of the area, the slope factor, the soil characteristics and the vegetation cover present in the area. Among all these factors the rainfall factor is most important. Topographic factor and vegetation cover also play quite important roles in determining the pattern of soil erosion in the study area.

STRATEGIES FOR SOIL CONSERVATION

Soil conservation strategies has to be based on the studies of the mechanics of detachment and transport of soil particles by rain splash and runoff. Thus conservation measures should involve protection of the soil from rainfall impact, increasing the infiltration capacity of the soil to reduce the volume of runoff and to improve the aggregate stability of the soil to increase its resistance to erosion. The northern mountain and the foothill region receiving greater amount of rainfall experience higher degree of soil erosion in general. The plains to the south, experience much lesser amount of soil erosion in comparison to the north. Thus the in the north suffering from greater degree of soil erosion, should be treated with more afforestation, adequate water drainage system and scientific terracing to check the problem of soil degradation. The mountainous parts are worst affected by landslides, which are a regular feature of these areas, due to the unstable nature of the hill slopes. In order to stabilise the hill slopes, afforestation on the slopes is a must. Also, stability can be increased by introducing terrace cropping. In the foothills area with lesser degree of slope but higher amount of soil erosion due to very heavy rainfall, the most effective way of soil conservation is to increase the vegetation cover, be in the form of quick growing species of trees or in the form of intensive root spreading grasses. Application of organic matter in the soil also help in increasing the compactness of the soil, thus reducing the erosion hazard. Where land use management alone is insufficient in preventing runoff on the hill slopes, the excess water has to be removed without causing erosion, whereby a network of waterways is constructed comprising diversion ditches, grass waterways and where terraces are integrated in the system, terrace channels.

The plains in the south are less vulnerable to soil erosion than the north, but certain conservation measures should be adopted to prevent the area from further erosional hazard. In such areas crop cover should be increased so that the soil is not left bare. If possible, the area should be brought under afforestation schemes. The land use of the area should be best suited to its soil type and awareness of the people should also be increased. Crop rotation and strip cropping should be introduced. Contour bunding with suitable waterways should also help in checking soil erosion.

The acute human interference in the natural landscape has aggravated the problem of soil erosion. The forest cover has also decreased. Thus, the human factor has become an additional factor in loosening the compactness of the soil in the interfluve area. Unless immediate conservation measures are adopted, the result will be more and more adverse to the ecological setup.

# CHAPTER V

# CHANGES IN THE LAND USE OF THE INTERFLUVE FANS- BALASAN AND MAHANADI

It is indispensable to know the exact nature and location of the different current land uses in the area. Land use describes how a parcel of land is used (such as for agriculture, residences or industry), whereas land cover describes the materials (such as vegetation, rocks or buildings) that are present on the surface (Sabins, 1992). The term "land utilisation" denotes the innate character of the land, that means whether a land remains barren or under forest cover, or covered with cultivated crops, roads, etc. Accurate, current information on land use and cover is essential for many planning activities. The change in such land use due to physical or cultural or a combination of both the factors, is a study of great interest as the influence of the physical and socio-economic factors on such changes should be understood in order to plan sound measures for the improvement and sustainable use of the areas under study.

The conventional method of classifying the land use categories is by the revenue classification (ICAR, 1980). This type of classification is in use by the revenue and agricultural departments and the classification is very elaborate in nature. However, this type of classification is very difficult to represent on land use maps.

Topographical maps are in wide use for preparing land use maps. Topographical maps published by the Survey of India are the best way of preparing land use maps. Where topographical maps are not available, aerial photographs can be used as a substitute as the mosaics of land use are easily identified on aerial photographs also. For preparation of detailed land use maps topographical sheets on 1:250,000 scale are ideal, but for preparing general land use maps where very minute details need not be shown, topographical maps of 1:50,000 scale can also be used. The different land use categories used by the revenue and agricultural departments and those which can be shown on toposheets are as follows:

Table 5.1: Land use categories by different classification

| Revenue classification of land use | Land use classification on toposheets |
|---|---|
| 1. Forests<br>2. Land under nonagricultural use<br>3. Barren and unculturable land<br>4. Permanent pastures and other grazing land<br>5. Miscellaneous tree crops and groves, not included in the net sown area.<br>6. Culturable waste land<br>7. Current fallows<br>8. Other fallow land<br>9. Net sown area | 1. Forests<br>2. Scrub and open jungle<br>3. Unproductive or absolute waste land<br>4. Marsh<br>5. Water features<br>6. Cultivated land<br>7. Settlements<br>8. Mixed or transitional |
| Source:ICAR, 1980 | Source: Rao, 1956 |

In recent years, satellite imageries are also being used for land use surveys. Satellite data can provide information on large areas and the temporal data can be utilised for change detection and updating old data. The land use categories that can be obtained from the remotely sensed data include Level I classes land use classification system such as forest, water bodies, grass land, agricultural land, barren land, scrub land, etc. However, more detailed classification is not possible from satellite data. The false colour composits (FCC) can be very useful for identifying the broad categories. Digital image processing as well as visual interpretation can be used, though, digital image processing can give more accurate and detailed information. Ground checks are necessary for identifying the different categories of land use identified on the imageries. The land use categories identified from the false colour composits by visual interpretation in the study area are : 1) cultivated land, 2) tea gardens, 3) open lands, 4) settlements and 5) current fallow.

Even at the beginning of the $19^{th}$ century, all these areas were under the cover of dense tropical forests mainly growing Sal, Segun or Shesham (Darjeeling District Gazetteer, 1980). But with the gradual establishment of an ordered government in the area and with increase in prosperity, the population in the area increased rapidly, with the consequent increase of pressure on land for cultivation of food and other crops. Moreover, in constant need for fuel, the poor farmers and agricultural labourers encroach upon the forests. Reservation of forests in the district started in 1866 and despite the fact that most of the forested areas of the district are administered as reserved or protected forests, the proportion of forests has been steadily declining. Thus, with the increase in pressure of population and the hazard of high degree of soil erosion at places, land use pattern has been changing constantly.

## DEFINITION OF DIFFERENT LAND USE CATEGORIES

In order to study the change in land use in the Balasan-Mahanadi interfluve fan areas, a village level study has been done for the years 1971 and 1981. Data for 1991 were not updated. The land use patterns of the villages have been divided into five categories(District Census Handbook, Darjeeling, 1971):

Forest: This includes all lands classed as forests under any legal enactment dealing with forests. This may be owned by the State or by any private individual. Land maintained as potential forestlands have also been treated as forests. Any other area used for any other purpose but situated within the forest so defined, is treated as forest.

Irrigated land: It relates to the land, which has actually been irrigated under different types of irrigation for the purpose of cultivation.

Unirrigated land: All areas under rainfall crops or under dry rice cultivation have been classified as unirrigated areas.

Culturable waste: It is defined as the lands within cultivated holding which have not been cultivated during the current year and the last five years or more in succession. Such lands may be either fallow or covered with shrubs and jungles. Land under thatching grasses bamboo bushes and other groves for fuels etc.which are not included under orchards or forests and land grazing, meadows etc. have also been included in this category.

Area not available for cultivation: This stands for barren, uncultivable land and land put to nonagricultural use. Barren and unculturable lands within cultivable holdings, which cannot be brought under cultivation without incurring a high cost, are also included. Land put to nonagricultural use stands for all lands occupied by buildings, roads and railways or under water, e.g., rivers, canals, etc.

IMPACT OF POPULATION GROWTH ON CHANGE IN LAND USE

The early settlers in the district were mostly agriculturist. The Superintendent of Darjeeling, Campbell, in the first half of the 19th century gave them every encouragement to reclaim forestlands and settle down there. The most potent factor contributing to the growth of population had been the tea industry. From around 1856, immigration of plantation labour caused by the opening of the gardens has been a major factor in the population growth in the district. Newly reclaimed lands for agricultural uses also encouraged immigration. Immigration has been the single largest factor in the growth of population of the district, but emigration from the district has always been negligible.

Table 5.2: Trend of population growth and immigration in Darjeeling district.

| Year | Population | Growth in % (1901 base year) | Immigration | % of total population |
|---|---|---|---|---|
| 1901 | 249117 | - | 113588 | 45.6 |
| 1911 | 265550 | 106.6 | 111269 | 41.9 |
| 1921 | 282748 | 113.5 | 101807 | 36.0 |
| 1931 | 319635 | 128.3 | 100700 | 31.5 |
| 1941 | 376369 | 151.1 | 95750 | 25.4 |
| 1951 | 445260 | 178.7 | 100311 | 22.5 |
| 1961 | 624640 | 250.7 | 169250 | 27.1 |
| 1971 | 781777 | 313.8 | NA | - |
| 1981 | 1005525 | 403.6 | NA | - |

Source: Darjeeling District Gazetteer,1980

Immigration from Nepal into the district has always been quite large. Immigration from other Indian states into the Darjeeling district has also been high. For example in 1961, it was found that there were more immigrants from Bihar than any other states of India. During the decade 1951-61, the Siliguri sub-division had shown a spectacular increase of population to the tune of 68.04% (Census of West Bengal, 1961). This high increase has been attributed to immigration into the district from the neighbouring countries and the neighbouring states of India, as well as due to natural growth of population. This increase has been shared by both the tracts under command of agriculture and rapidly growing urban areas centering on Siliguri. A number of Tibetans have also come over after the Chinese occupation of Tibet.

The number of immigrants declined during the year 1941-51(22.5% of the population) due to a recession in the tea industry. Settlement of displaced persons in different parts of the district has had a great bearing on the growth of population. In the census of 1961, as many as 169250 persons have returned themselves as being born outside the district, which constitute 27.1% of the total population of the district ( Census of West Bengal, 1961). During the ten year period, 1951-61, the immigrant population came mostly from East Pakistan, Nepal and Bihar. Some part of this immigrant population also came from the neighbouring districts of Jalpaiguri, Cooch Bihar and West Dinajpur, showing a great increase in the district population during that period (District Census Handbook, Darjeeling ,1961). Immigrant refugees, mostly Bengali Hindus, from the former East Pakistan form a quantitatively important segment of the population of the district nowadays, most of whom have settled in the plains of the district within the Siliguri subdivision. In 1951, 15738 persons immigrated to the district from East Pakistan, while the number increased to 38162 in 1961. It was found that over 57% of the total immigrants from East Pakistan in 1961 lived in urban areas (mainly Siliguri) and less than 43% had settled in the rural areas of the district.

This continuous inflow of population into the district has led to increased pressure of population within the district. The villages situated within the Balasan – Mahanadi interfluve fans have also experienced changes in population pressure, mostly in the positive direction. The study area as a whole, covering parts of the Kurseong and Siliguri Police Stations have also registered very high growth rate in total population. While the total population in the study area was 39552 in 1971, it increased to 69021 in 1981, showing a growth rate of 74.51 % over the 1971 population. The population increased to 85551 in 1991, the growth rate being 23.95% over the 1981 population. The growth of population between 1971 and 1981 has been very high, the growth being the result of natural growth and immigration into the district from the neighbouring districts and the neighbouring countries. Immigration from Bangladesh has also been very high during this decade. However, the growth rate during the period 1981-91 has been much lower than in the previous decade, the growth being the result of natural growth mainly and lesser amount of immigration into the district.

By studying the data of land use for 1971 and maps of the villages situated in the Balasan – Mahanadi interfluve fan areas, it can also be seen that the forest cover in most of the villages of Siliguri PS remained between 0 and 15% only (appendix ii). Data was not available for most parts of the Kurseong PS, but it is assumed that the percentage of forest cover was somewhat higher than in the Siliguri PS. Due to the undulating character of the topography, the areas are less suitable for human settlement and are more favourable for tea plantations and forest cover. Percentage of uncultivated area was very high (between 70 and 100%) in the eastern part of Siliguri PS, and comparatively high (between 40 and 70%) in the rest of the area. Culturable waste area are also relatively low (between 0 and 15%) in most parts of the Siliguri PS, except for a few pockets where they are higher. However, percentage of area not available for cultivation i.e., mostly settled areas show a distinct negative relation with cultivated areas. Where area under cultivation is very high, in the eastern villages of the study area, settlements and other uncultivated areas occupy less than 30% of the total area.

But where cultivated lands cover lesser areas, i.e., in the western parts of the study area, the percentage of area not available for cultivation are much higher, ranging between 30 and 605 of the total area. Thus, the western villages of the Siliguri PS are more settled and have lesser amount of cultivated lands. The eastern villages of the police station have more cultivated area and less area under other uses, such as settlement. The population density (persons/hectare) is moderate in the entire Siliguri and Kurseong police stations, remaining below 40 persons/ha. Most of the villages in this category have less than 15 persons/ha. Very few villages in the entire study area have more than 40 persons occupying each hectare.

Change in population density from 1971 to 1981 has been low in all the villages of Kurseong PS and in some of the villages of Siliguri PS (-100 to 250% change, appendix iii). Some of the villages that were moderately populated in 1971, have shown negative change in population density. In most of these villages, density change is due to change in land use over the years. Like in the villages Sukna Part I(JL no.6), Rupan Chhat (JLNo. 40), Matigara Hat (JL. No. 80) in Siliguri PS, unirrigated agricultural land has been changed over for some over uses and in all these cases, area not available for cultivation has increased. Shrinkage in cultivable area in these villages has led to out migration of village members. Areas have also been taken over by the defence sector in some parts of the study area, resulting in the out migration of the local population.

Change in population density have been high and very high in a number of villages in Siliguri PS. For example, in the village Khaprail (JL No 14), area under cultivation, both irrigated and unirrigated, have been reduced to some extent and area under culturable waste have undergone a remarkable change in the positive direction. Areas not available for cultivation have been reduced greatly. Number of population in this village has increased from 339 in 1971 to 1428 in 1981. There is a large army base in Khaprail, which developed during the 1970's, resulting in decrease in cultivated area, increase in culturable waste and considerable increase in population density (321.33% in 1981 over 1971). In both the villages of Malahar (JL No. 46) and Mahishmari (JL. No.47), area under cultivation and culturable waste have been reduced and area not available for cultivation have increased. In these areas also, change in land use in favour of other uses have attracted population from elsewhere. The case is same in the village Mahatram (JL No. 50), where density of population has increased greatly due to great increase in number of population (from 121 in 1971 to 1761 in 1981). The scene is somewhat different in the village Baniakhari (JL. No. 55), where total area under cultivation has increased greatly due to introduction of irrigation which resulted in the increase in agricultural population in the area. In the village Daknikata (JL. No. 83), growth in population density was very high (2156.41 % in 1981 over that in 1971) due to change in land use in favour of other uses at the expense of cultivated area.

Thus, the changes in land use and population density from 1971 to 1981 are clearly interlinked. Mostly increase in agricultural lands has resulted in migration in agricultural population to the villages. Migration of people to the defence estates and around them also resulted in increase in population densities in some of the villages. The population of the villages where defence estates have been established has increased largely.

Increase in agricultural land in the Balasan–Mahanadi interfluve area has also resulted from increase in area under irrigation to some extent. Artificial irrigation is common in the area. Along the Balasan and Mahanadi rivers, it is generally easy to dam up the streams and construct water channels. Water from these sources are conveyed to the fields, sometimes situated at a long distance through irrigation channels, locally known as "ponris". The big rivers are generally low and shallow in the Terai area and they scarcely serve the purpose of irrigation. The smallest streams are generally dammed up and their water is diverted into channels. The appliances used for irrigation are very primitive and consists usually of a bamboo basket by means of which water is bailed out by hand whenever necessary. Well irrigation in the area is practically unknown. However, agriculture is heavily dependent on rainfall, to the extent of about 80% of the total cultivation of the area.

LAND USE STUDY FROM TOPOSHEETS AND SATELLITE IMAGERIES

The land use data for 1991 are not available, and thus detailed village wise study and the role of change in population density could not be carried out. However, the land use in the study area in 1990's has been studied from satellite imageries. The land use for the northern part of the interfluve area covered in the toposheet no. 78B/5 have been studied from the toposheet (land use for1969-71) and a later version of the land use situation has been from the IRS-1B LISS II imagery for winter 1992. The land use of the southern part of the area covered in the toposheet no. 78B/6 could not be studied during the 1960's as there were no publication during that period. The land use change of that region through the 1990's have been studied with the help of three satellite imageries for the years 1990,1994 and 1997, all for the winter season.

The imagery used for the area covered by the toposheet no. 78B/5 is an IRS 1B, LISS II imagery, acquired on 30.3.92. The two imageries covering the southern part of the study area (toposheet no. 78B/6) acquired on 19.1.94 and 1.1.97 are also IRS 1B LISS II imagery. The imagery used for studying the same area for 17.11.1990 was acquired by the French satellite SPOT I , using HRV2 scanner.

The High Resolution Visible (HRV) imaging system is the type of scanner used on board SPOT satellites that produce stereoscopic images and the spatial resolution for multispectral mode is 20 mt. There are two identical scanners present in the SPOT satellites, HRV1 and HRV2. These scanners can also operate in panchromatic mode. The spectral bands in use for acquiring the scene where bands 1(0.5-0.6μm, green band), 2 (0.61-0.68 μm, red band) and 3 (0.79-0.89 μm, near infrared band).

The Linear Imaging Self Scanning System (LISS) I and II scanners installed on board the Indian satellites IRS 1A and IRS 1B , are identical in nature. The LISS I scanner has a spatial resolution of 72.5 mt. and the resolution of LISS II is 36.25 mts. The LISS II uses Medium Resolution Camera(MRC). Each camera system images in four spectral bands in visible and near infra red regions. The spectral bands used for acquiring the scenes on 30.3.92, 19.1.94 and 1.1.97 were bands 2(0.52-0.59μm, green band), 3(0.61-0.68μm, red band) and 4(0.77-0.86μm, near infra red band).

Land use changes for the northern part of the study area (78B/5) have been studied over the period 1969-71 and 1992 (Figs V.1 and V.2). It is evident from comparing the two maps that forest cover has shrunk northwards to a considerable extent all over the area. This area falls within the Sukna-Tista Reserve Forest, but still the migration of the boundary northwards has been very fast. For example, forest area between the Rivers Rakti and Panchanai has been totally depleted and that area has been taken over for the purpose of cultivation mainly. To the east of the railway line to Darjeeling also, the forest limits have been pushed northwards. This is a direct result of increase in pressure of population in the area. Nowadays forest limits are restricted to the mountainous part of the study area only. Area under tea gardens has also decreased over the years. For example, in 1964-65 the Rohini tea garden situated between the Rakti and Rohini Khola had its extreme northern part deserted and plantation was carried out on the rest of the area. But in the 1990's it is found , that almost the entire area has been deserted and plantation is carried out only in a small part. The northern part of the garden is now under forest cover and the southern part is either partially forested or open land. This open land is nowadays used by the military for target practicing. The area of the Gulma tea garden has also been reduced and the area is utilised for agricultural practices. The change in area under different land use over the years for the northern (78B/5) and southern (78B/6) parts of the study area has been presented in the following table

**Land use in the northern part of the Mahanadi-Balasan interfluve (1969-71)**

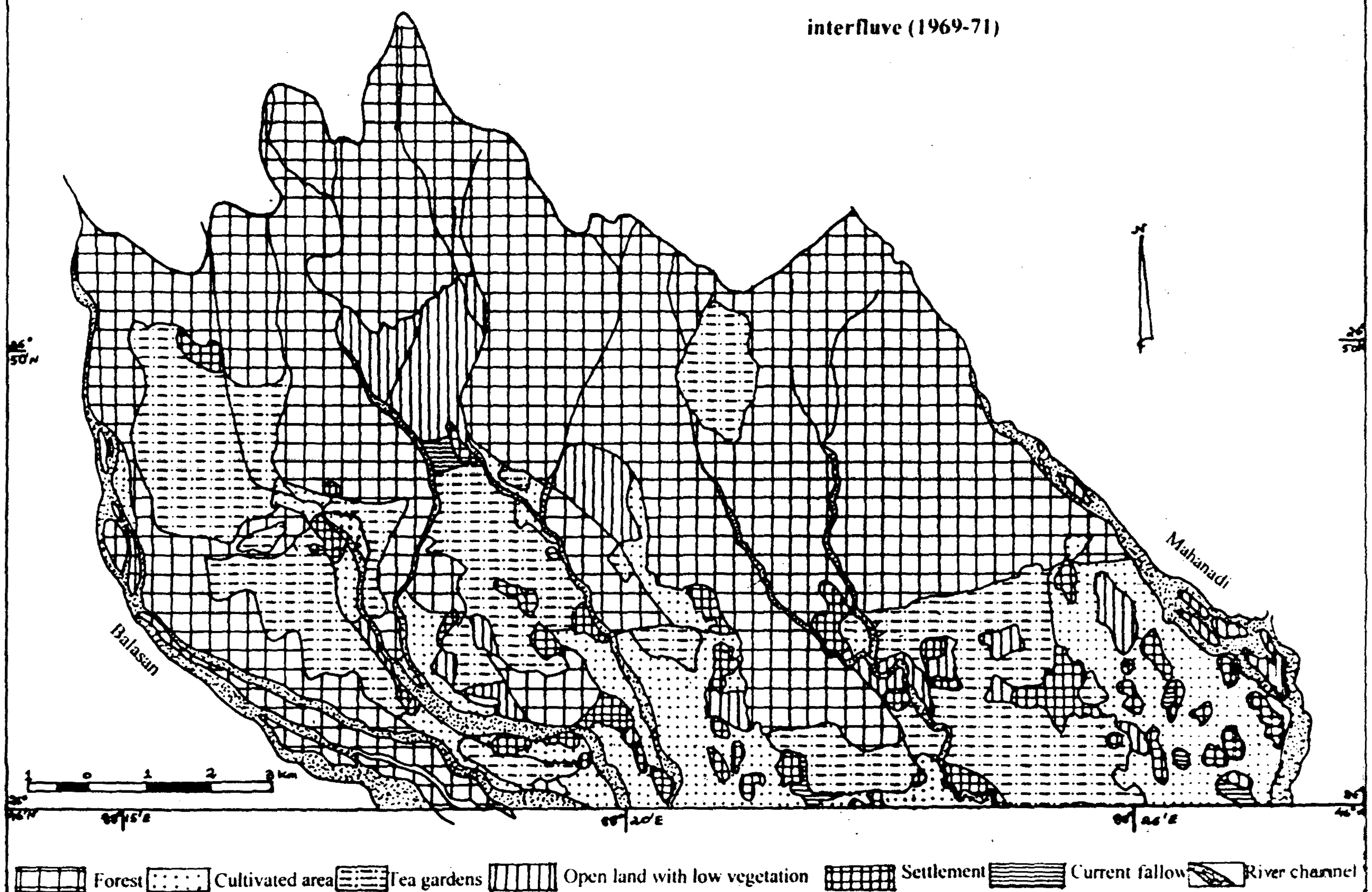



FIG V.1

Source : Toposheet No. 78 B/5

**Land use in the northern part of the Mahanadi-Balasan interfluve (1992)**

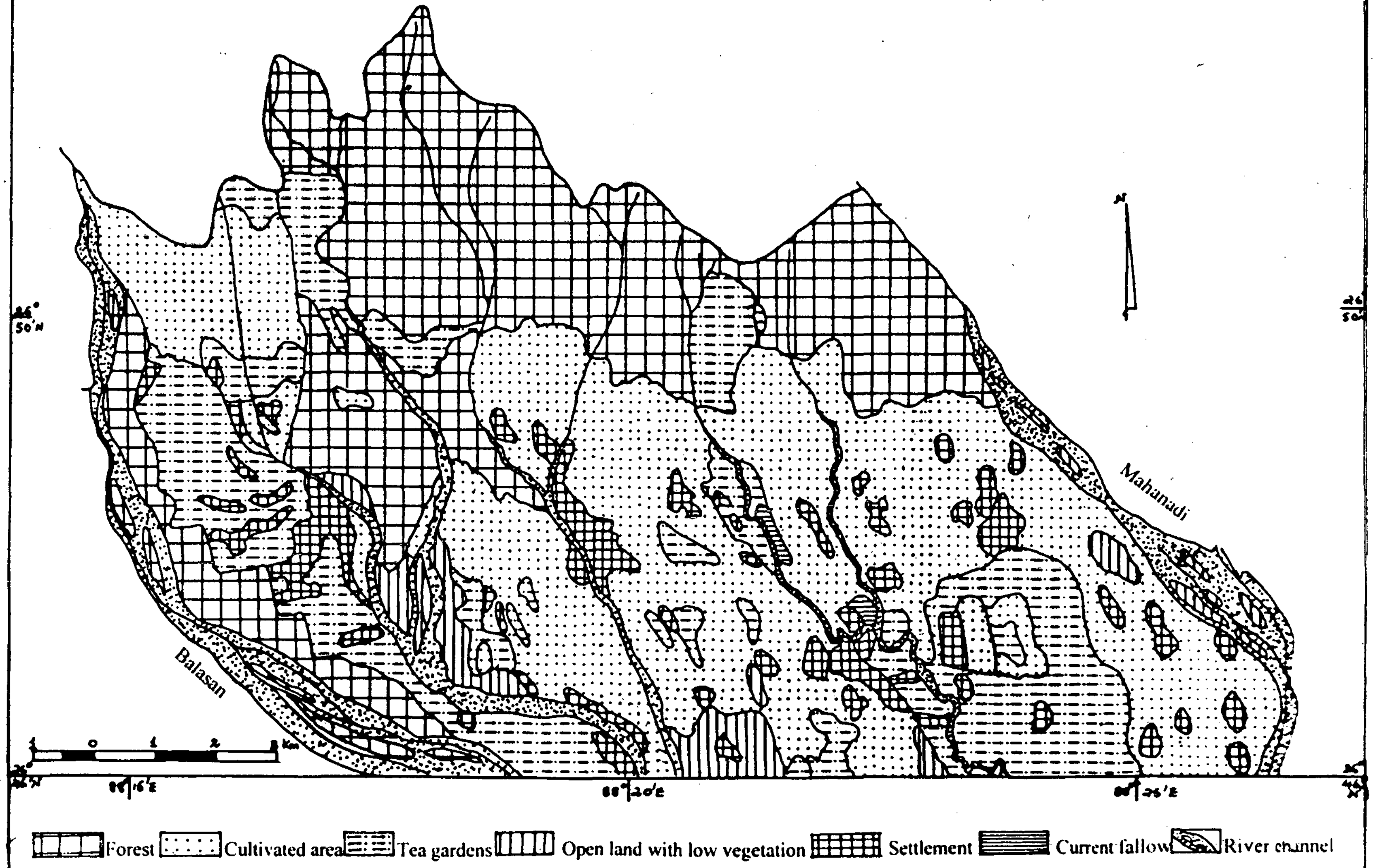
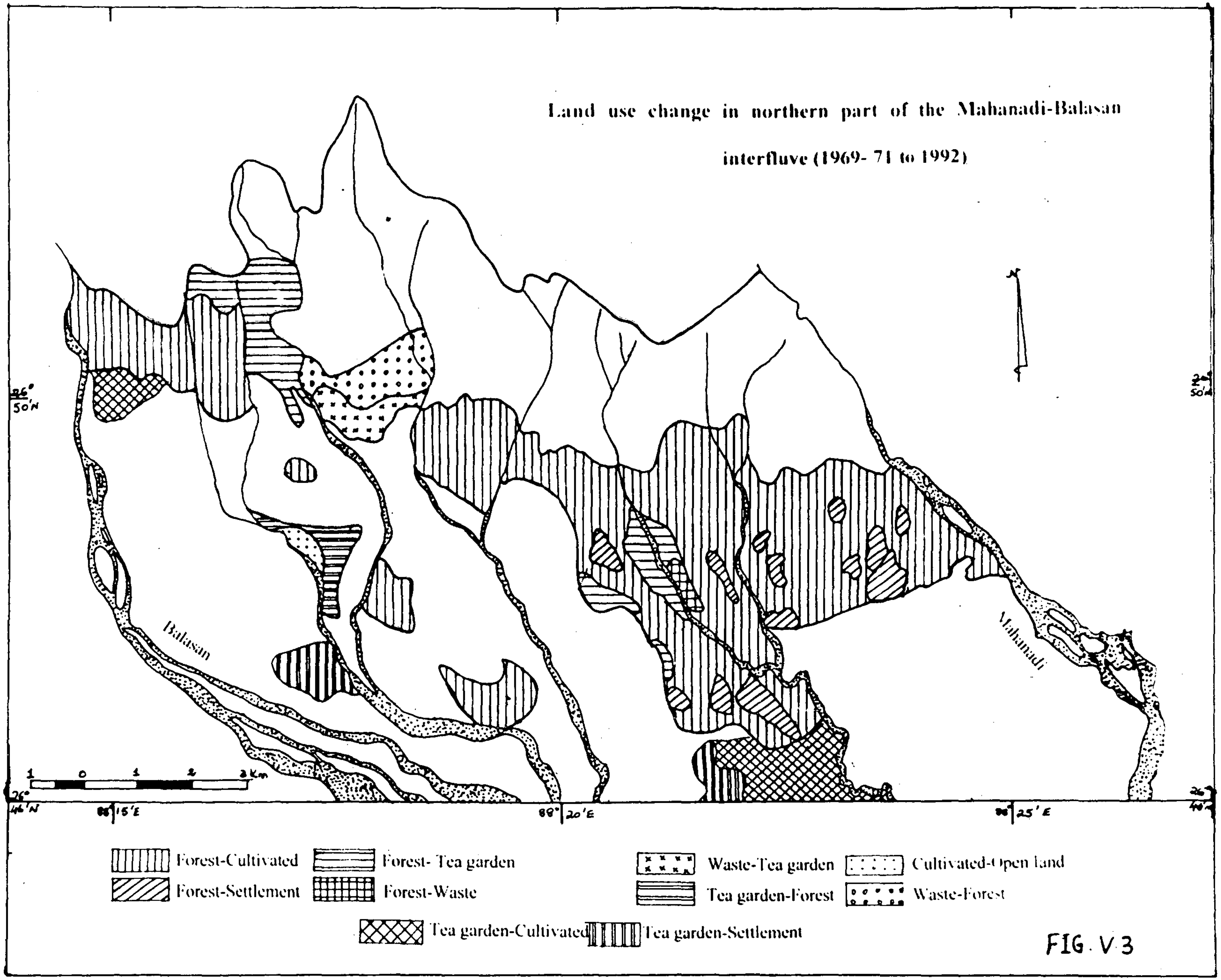



FIG. V-2

Source : IRS IB, LISS II date : 30.3.92




**Land use change in northern part of the Mahanadi-Balasan interfluve (1969- 71 to 1992)**

FIG. V.3

Table 5.3: Area under different land use.

| Land use category | Nn. part of study area 1969-71 | 1992 | Sn. Part of study area 1990 | 1994 | 1997 |
|---|---|---|---|---|---|
| Forest | 51.23 | 46.77 | - | - | - |
| Tea garden | 29.25 | 24.56 | 10.81 | 8.93 | 12.28 |
| Cultivated | 23.44 | 54.14 | 11.25 | 13.75 | 14.56 |
| Open land | 7.73 | 5.18 | 7.56 | 11.46 | 7.45 |
| Settlements | 7.38 | 10.08 | 12.88 | 9.76 | 9.50 |
| Current fallow | 1.00 | 0.30 | 0.95 | 0.14 | - |
| Channel area | 15.75 | 14.35 | 10.75 | 10.79 | 11.00 |
| Total area | 135.78 | 134.38 | 54.20 | 54.83 | 54.79 |

Thus, the general trend all over the area is northward migration of the forest limits and replacement of the forested lands by cultivated area. Cultivation all over the region has increased to a great extent. Areas of tea gardens have also been reduced and some tea gardens have been totally abandoned, to be replaced by wastelands and open area. Settlements have also increased in number and area, indicating increasing density of population over the area. Establishment of defence estates has also resulted in increase in population in some areas. The change can be clearly understood from Fig. V.3.

Comparison of land use in the southern part of the study area (78B/6) over the years 1990, 1994 and 1997 reveals a dynamic nature of the land use in this area (Fig. V.4,5 and 6). Between 1990 and 1994, areas of the Dagapur and Chandmari tea gardens were reduced to some extent and New Champta tea garden gained some area. This tea garden grew at the cost of cultivated area, as some cultivated area was brought under plantation. Area of Patanbari tea garden remained constant. Open areas, lying vacant with very low vegetation cover were converted to agricultural lands. However, at places cultivated areas were also converted into vacant area. Settled areas have almost remained constant with some minor additions. These additions in settled areas are due to development of settlements caused by increase in population over the years.

**Land use in the southern part of the Mahanadi-Balasan interfluve (1990)**

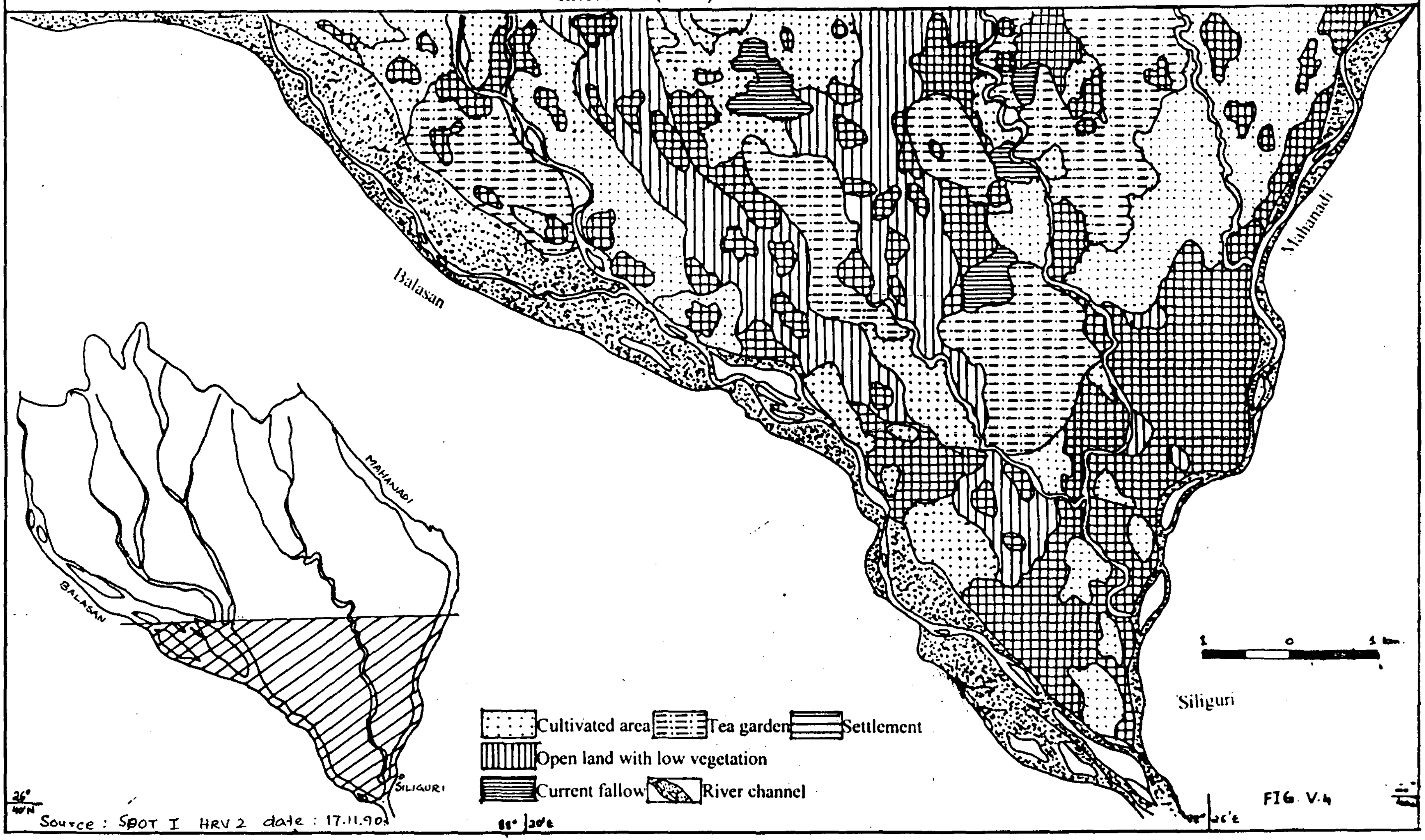
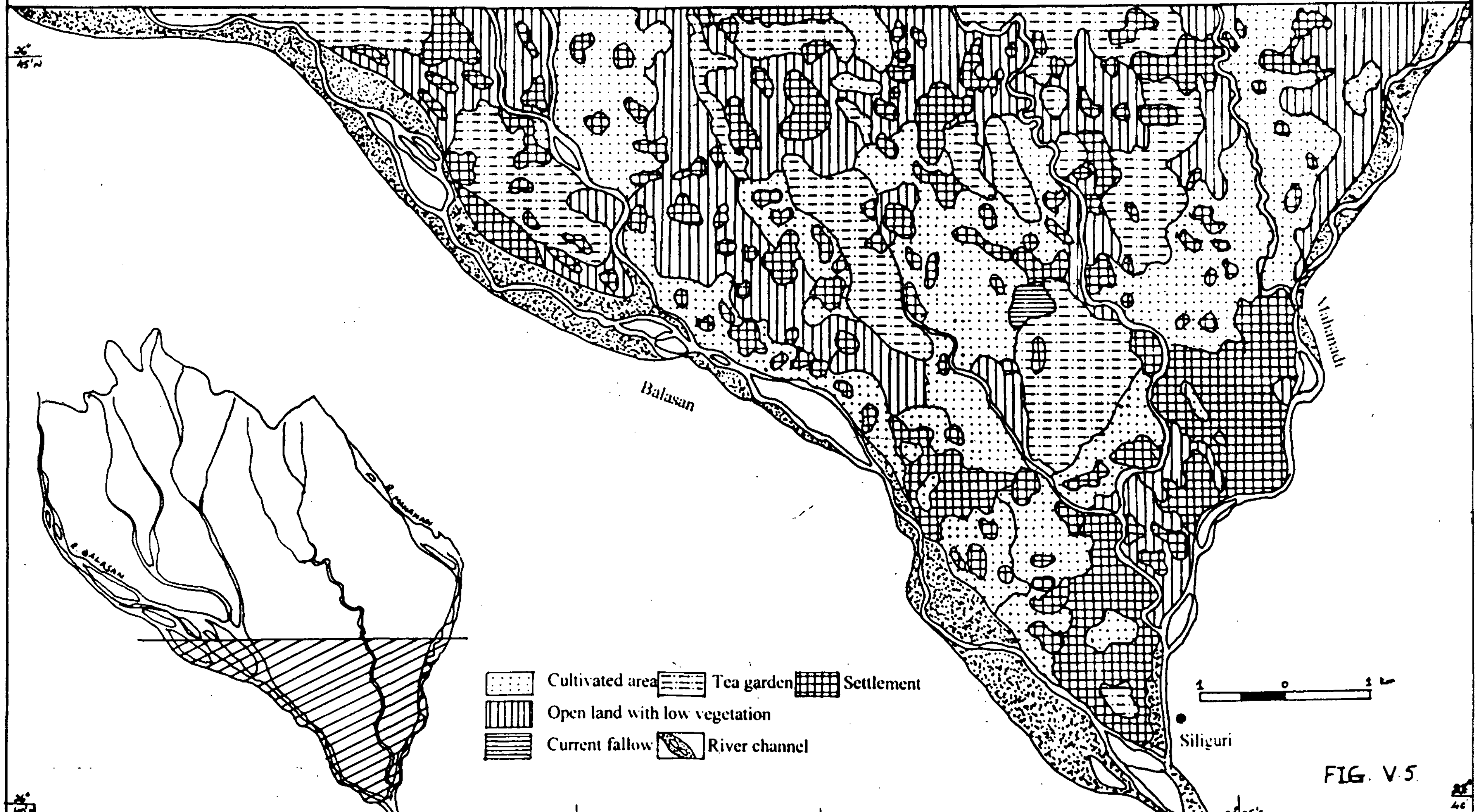



FIG. V.4

**Land use in the southern part of the Mahanadi-Balasan interfluve (1997)**




Source: IRSIB, LISS II date: 1.1.97

FIG. V.5

**Land use in the southern part of the Mahanadi-Balasan interfluve (1994)**

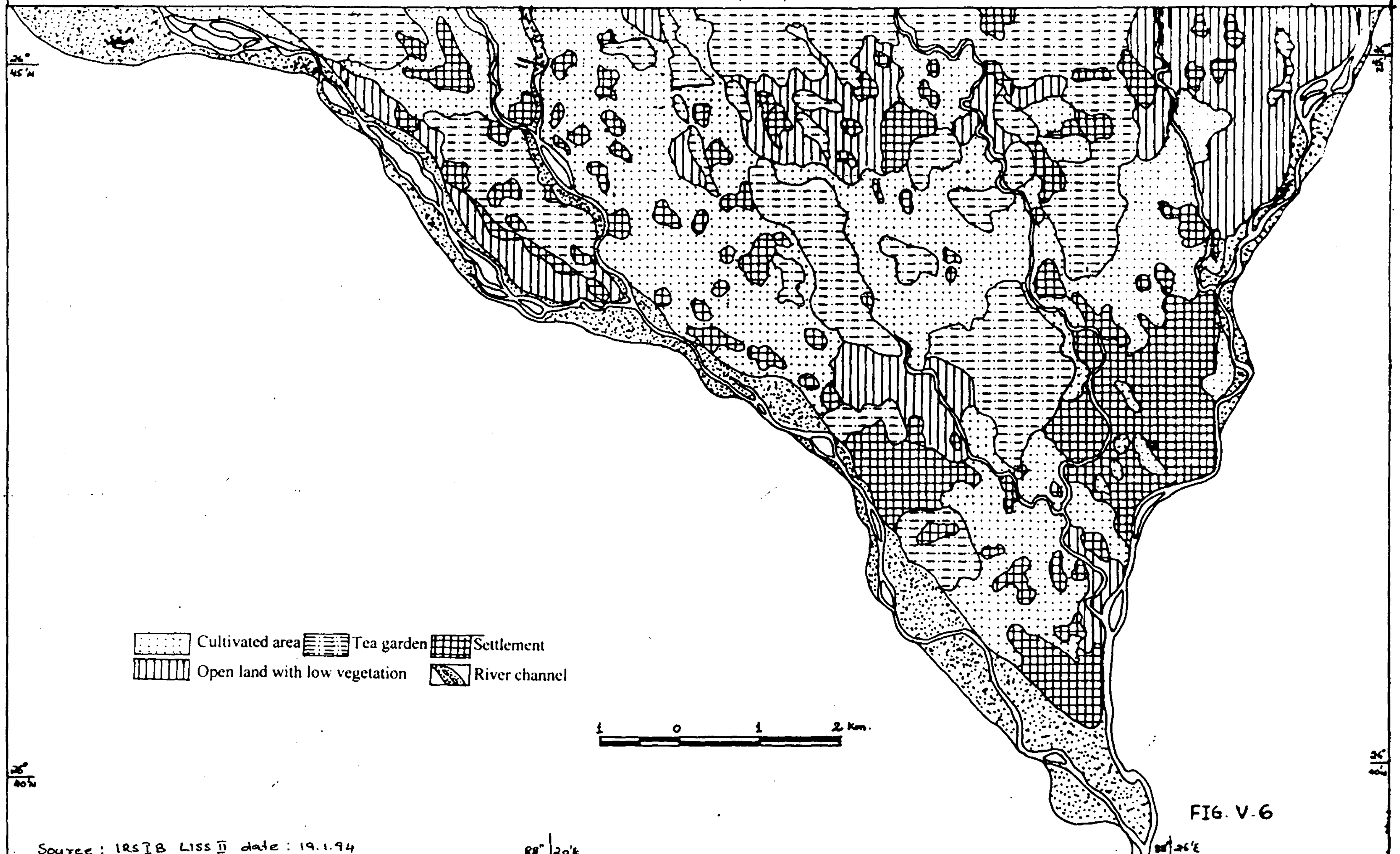



FIG. V-6

Source : IRS IB LISS II date : 19.1.94

Between 1994 and 1997, the major change is evidenced in case of open uncultivated land with low vegetation cover that have been brought under cultivation. Some of the settled areas of 1994 have been relocated as there was a flood in September 1995 that had inundated quite a large area in and around Siliguri. As a result of that flood, the confluence of the rivers Balasan and Mahanadi has shifted about a kilometer downstream. The change in land use between 1990 and 1997 is shown in Fig. V.7.

Thus, the dynamic nature of land use in the entire study area can be attributed to :

1) Physical conditions, like floods that result in course changes by rivers that lead to relocation of settlements that are inundated by floods.
2) Increase in demand for foodstuffs due to increase in population pressure lead to conversion of uncultivated open land with low vegetation cover into agricultural land and previously cultivated land into uncultivated tracts that become less fertile due to over use.
3) Increasing population lead to destruction of forest covers over the years due to the need for more area under cultivation. Increasing requirements of fuel also lead to destruction of forest cover by the ever-increasing population of the area.
4) Establishment of defence estates in some parts of the area after 1970 has attracted more population to those areas, and the prevalent land use has also undergone changes due to military occupancy.

Conversion of uncultivated fallow land with very less vegetation cover into productive cultivation is a move towards positive direction, however, increasing arable farming and overgrazing have profound effects on the existing soil cover. Excessive deforestation together with unplanned use of the fan surface accentuates the problem of soil erosion. The increasing population pressure and their encroachment in the foothills region result in deforestation, which forms the core of the problem. Thus, the Balasan- Mahanadi interfluve fan area requires

## Land use change in the southern part of the Mahanadi-Balasan interfluve (1990-1997)

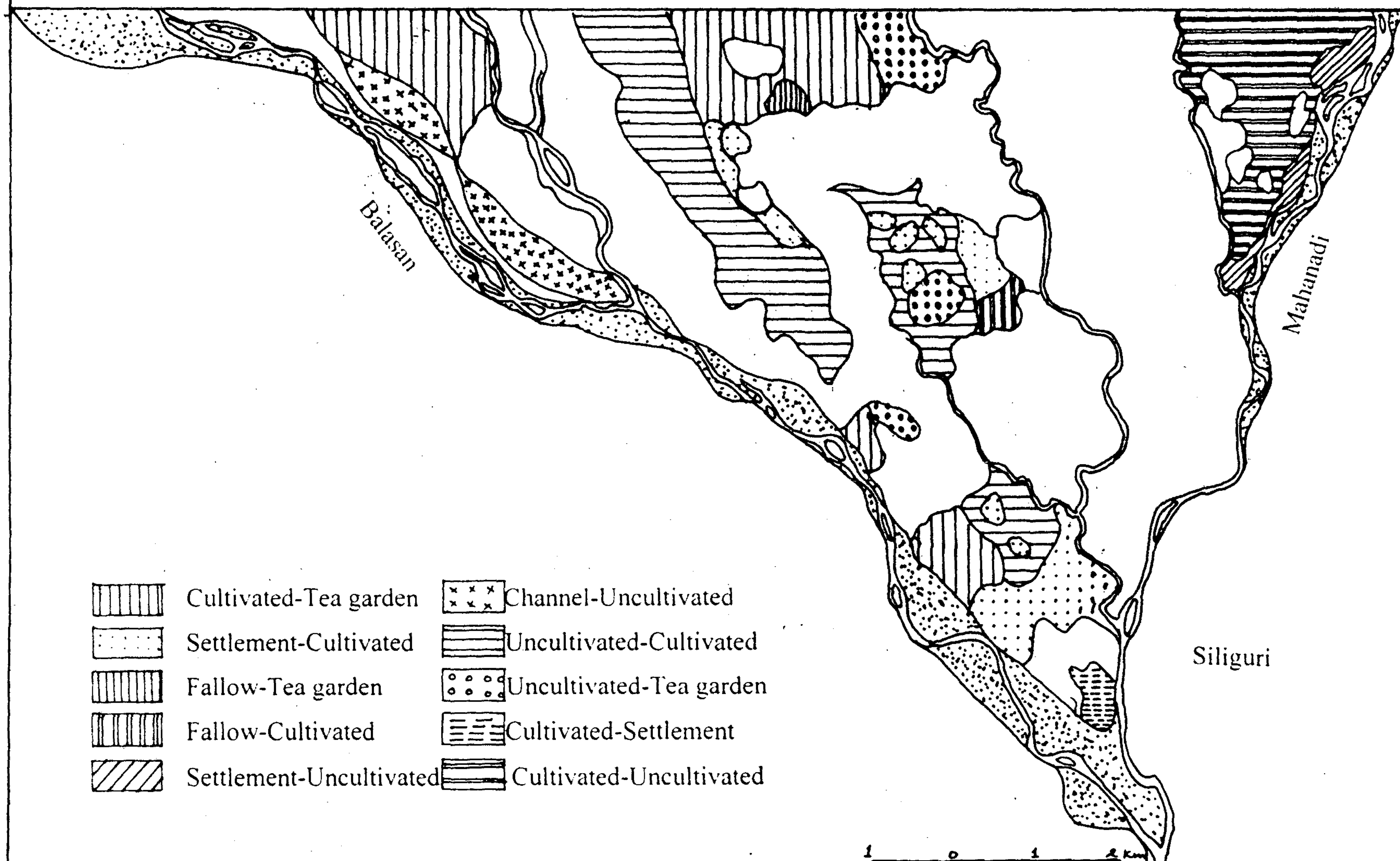



FIG. V.7

planning of land use in a scientific way in order to maintain the fragile ecological balance.

# CHAPTER VI

# CONCLUSION

Darjeeling, the northern most district of West Bengal consists of the Darjeeling Himalayas in the north and a flat undulating plain formed by river deposition known as the " Terai" in the south. This Terai region of the district is drained mainly by the River Tista and its tributaries, the important among them being the Rivers Mechi, Balasan, Mahanadi, etc. This region is a piedmont zone formed by the coalescence of the alluvial fans formed at the foot of the Darjeeling Himalayas by the rivers coming out of it. The Terai plain is mostly formed of alternating beds of sands, gravels and boulders brought from the hills either by the rivers or by the processes of debris flow or flash floods in these rivers. The Darjeeling hills experience numerous large and small land slides and land slips at various locations and these debris are also carried to the piedmont zone in the south by the rivers themselves and by the small jhoras and nullahs during spells of heavy rainfall. The Terai plain has a general slope from north to south and due to its almost flat and monotonous topography the rivers have braided courses. On their entry on the wide North Bengal plains from the mountains, they are free to subdivide and form wide braided channels. Due to a sudden change in the gradient of the rivers when they enter the plains from the hills the velocity of the rivers are suddenly checked, leading to their reduced transporting capacity. This sudden decrease in energy of the rivers lead to their braiding forming wide and shallow river beds. Since their carrying capacity are reduced, these rivers start depositing the materials they bring from the mountainous region. The deposition of these eroded sediments lead to the development of alluvial fans.

The higher reaches of the Himalayas are mainly composed of gneisses and mica schists, known as the Darjeeling gneiss, which are partly sedimentary and partly igneous ion origin. To the south of this zone lies the Daling series, formed mainly by a group of low grade metamorphosed sediment. The Gondwana formations are found in a narrow band between the Dalings in the north and the Siwalik group of rocks in the south. The foothills north of the Terai are made of compact alluvial detritus. This Siwalik group of rocks are of Tertiary age. The rivers carry the sediments from the higher hills and deposit on the Terai plains in the south. Thus, the alluvial fans are formed by the materials brought by the rivers flowing across various geological formation of the higher Himalayas.

The soils found on the alluvial fan surface are coarser in the northern part of the study area and finer towards the south. The sediment of the fan area are of transported origin with heterogeneous parent material. The deposits are coarse grained, poorly sorted and immature in nature, mainly in the upper and middle parts of the fan. Usually gravels, cobbles and boulders predominate with subordinate amounts of sand, silt and clay in the Balasan–Rakti-Rohini sector mainly. However, boulders, gravels and cobbles are almost absent in the Mahanadi sector. This is because of the fact that the former sector derive their sediment more from flash flood in the rivers and from debris flows. But the Mahanadi sector derives the sediments mainly from stream action and stream floods and thus they are finer in nature. In general the coarsest and the thickest deposits occur near the fan heads and the grain size and the thickness of sediments decrease rapidly towards the base of the fan deposits. The roundness of the coarse grains also increases with increasing distance from the apex of the fans.

Soil erosion is a serious problem faced by the area. The foothills region experience very high amount of soil erosion mainly because of lack of vegetation cover on the slopes and also due to very coarse and unconsolidated nature of the sediments. Landslides and land slips are regular phenomenon here that also leads to higher amount of soil erosion. Just below the foothills region the upper fan areas also experience quite high amount of soil erosion due to lack of forest cover and the land is being used for various uses. Some parts are also left vacant with very low vegetation cover. The slope of the land is also greater than in the lower reaches and the sediments are less consolidated. The lower reaches of the fans experience lesser amount of soil erosion than in the upper reaches. However, the amount of sand near the confluence of Balasan and Mahanadi are much higher and also the land is being very extensively cultivated. These factors all lead to soil erosion in this area.

The forest cover in the study area is fast diminishing. The area to the south of the latitude 26 45' N do not have any forest cover. The area to the north of it had extensive forest cover even in the 1960's but in the 1990's the southern limits of the forests have shifted northwards, the depletion being the result of illegal felling and encroachment of population into the forest lands. Forests are now a days restricted mainly to the foothill zone and in scattered patches in the south. Beside the rivers Balasan, Mahanadi, Rakti , Rohini and their small tributaries riverine forests are seen in scattered patches. The most important species found here are Sal and Sissoo. At the foothills dense forests of Sal are found, mixed with varying proportions of other species as well.

The plains of the Terai receive heavier rainfall than the mountainous parts in the north and 80% of the annual rainfall are concentrated during the monsoon months of June to September. The winter months remain quite dry.

The geomorphology, drainage pattern, soil characteristics, climate as well as increasing population pressure in the area is resulting in the changing land use pattern of the area. Geomorphologically, the area has been divided into upper, middle and lower fan areas depending on the slope and land use in all these geomorphological divisions vary. The upper fan area situated at the base of the hills have steeper slopes than the middle and lower parts, have coarser soils and drainage channels confined by steep escarpments. These areas are never inundated by flood waters but the more important fan building processes evident in these regions are flash floods and debris flows, resulting in their constant modification. The upper fan areas are mostly under forest cover though their areas are decreasing. The soil characteristics of the region are not suitable for cultivation, but tea gardens are very common in this region due to the undulating nature of the terrain. Since tea plants cannot survive under stagnant water, thus undulating topography which can be easily drained of excess water are essential for tea plantation. However, in the Mahanadi sector the upper fan area is mainly under forest cover. The hilly tracts of the north are prone to land slides due to unstable nature of the hills. These hills at places have very low forest cover that also helps in the occurrence of such land slides. Thus, afforestation of the hills in a scientific manner may also help in checking the land slides to certain extent.

The middle fan area of the Balasan-Rakti-Rohini was mainly occupied by tea gardens in the 1960's. But in the 1990's it is found that large areas under tea gardens have been abandoned and they lie vacant as open land with very low vegetation cover. Marchenbong , one such area formerly under Rohini tea garden near the apex of the Rohini fan now lie vacant and is used for target practicing by the army. In the Mahanadi sector, agricultural land has increased considerably mainly at the cost of tea gardens. This has resulted from increasing need for food crops due to increase in population pressure over the years.

The lower fan area are mainly affected by floods, of both the Balasan and the Mahanadi. This often result in change in the river course. Thus, the land use of this zone is mostly affected. Whenever there is a flood large areas get inundated and receive fresh sediments from the rivers. Area under cultivation is on the increase zone, mainly because of increasing population pressure. Moreover this region having finer and more fertile soils are suitable for cultivation. The soil like in the upper and middle fan areas do not have boulders, pebbles and cobbles, resulting in it being more fertile for agriculture. Many areas lying vacant with very low vegetation cover were brought under cultivation with help of irrigation water. Increase in area under irrigation is helping in converting the vacant lands into cultivated ones.

This changing land use pattern all over the fan areas are having negative impact on the delicate ecological balance of the area. Depletion of forests and increase in agricultural land are having profound effect on the soil of the region.

Over utilisation for cultivation and deforestation is accentuating the problem of soil erosion. The unplanned use of the fan surface in an unscientific manner due to increase in population pressure leads to other problems as well. This unplanned use of the fans has set the vicious cycle of deforestation, soil erosion, mass movements and floods. The forces of nature cannot maintain any equilibrium due to this unplanned use of the land resource. The cultural impositions by man, on the other hand have induced the natural forces to remain ever active. Thus, the morphology of the Balasan-Mahanadi interfluve fan area is also being gradually modified. Thus, it is required to have a careful planning so that the ecological balance in this area of dynamic land form is maintained.

Appendix i

**LAND USE 1971**

P.S. SILIGURI

| JL. NO | VILLAGES | POP | AREA | FOREST | IRRI. | UNIRRI | CULT W. | NAC |
|---|---|---|---|---|---|---|---|---|
| 5 | Mahanadi Forest | 159 | 1021.82 | NA | NA | NA | NA | NA |
| 6 | Sukna, Part I | 1933 | 25.11 | 0 | 0 | 25.11 | 0 | 0 |
| 7 | Sukna Forest | - | 332.91 | NA | NA | NA | NA | NA |
| 8 | Kamalabarir Chhat | Incl. in 9 | 25.52 | NA | NA | NA | NA | NA |
| 9 | Khoklong Chhat | 660 | 36.86 | 0 | 0 | 16.20 | 0 | 20.66 |
| 10 | Paharu | Incl. In 11 | 70.07 | NA | NA | NA | NA | NA |
| 11 | Chota Adalpur | 320 | 77.76 | NA | NA | NA | NA | NA |
| 12 | Khoklong | 914 | 119.48 | NA | NA | NA | NA | NA |
| 13 | Bara Adalpur, Part II | 83 | 183.47 | NA | NA | NA | NA | NA |
| 14 | Khaprail | 339 | 449.96 | 0 | 0 | 247.05 | 16.61 | 186.3 |
| 15 | Patanjharer Chhat | 1091 | 14.18 | NA | NA | NA | NA | NA |
| 16 | Fulbari Chhat | 564 | 29.57 | NA | NA | NA | NA | NA |
| 17 | Patan Chhat | Incl. In 15 | 71.28 | NA | NA | NA | NA | NA |
| 18 | Patan | Incl. In 15 | 50.22 | NA | NA | NA | NA | NA |
| 19 | Fulbari Pataner Chhat | Incl. In 16 | 66.02 | NA | NA | NA | NA | NA |
| 20 | Ruhinir Chhat | 965 | 18.23 | NA | NA | NA | NA | NA |
| 21 | Khopalasi | 722 | 170.51 | 0 | 0 | 106.92 | 10.13 | 51.84 |
| 22 | Jhauguri | 234 | 88.29 | 0 | 0 | 57.51 | 11.75 | 19.04 |
| 23 | Jhauguri Chhat | 69 | 77.36 | NA | NA | NA | NA | NA |
| 24 | Rajpairi | 505 | 210.20 | 0 | 0 | 113.00 | 29.16 | 68,04 |
| 25 | Chamtaguri Chhat | 47 | 19.05 | 0 | 0 | 8.51 | 3.65 | 6.89 |
| 26 | Chamta | 458 | 193.19 | 0 | 0 | 118.26 | 15.8 | 59.13 |
| 27 | Panchanai | 499 | 135.27 | 0 | 0 | 60.75 | 64.8 | 9.72 |
| 28 | Nunu Bairagi | 697 | 104.49 | NA | NA | NA | NA | NA |
| 29 | Nunu Bairagi Chhat | Incl. In 6 | 74.52 | NA | NA | NA | NA | NA |
| 30 | Mohargong T.E. | 2238 | 856.58 | 0 | 0 | 591.3 | 20.25 | 245.03 |
| 31 | Purba Karaibarir Chhat | Incl. In 30 | 49.82 | NA | NA | NA | NA | NA |
| 32 | Gulmakhari | Incl. In 30 | 63.18 | NA | NA | NA | NA | NA |
| 39 | Karaibari | 221 | 158.76 | 0 | 0 | 121.50 | 16.2 | 21.06 |
| 40 | Dariagramer Chhat | 1644 | 7.70 | 0 | 0 | 3.65 | 0 | 4.05 |
| 41 | Shishabari | 470 | 127.17 | 0 | 0 | 109.35 | 0 | 17.82 |
| 42 | Rupan Chhat | 50 | 2.43 | 0 | 0 | 2.03 | 0 | 0.40 |
| 43 | Palash | 619 | 221.54 | 0 | 0 | 202.50 | 8.51 | 10.53 |
| 44 | Kalkut | 274 | 145.8 | 0 | 0 | 121.50 | 12.15 | 12.15 |
| 45 | Kalabari | 425 | 77.76 | 0 | 0 | 76.95 | 0 | 0.81 |
| 46 | Malahar | 66 | 35.24 | 0 | 0 | 32.40 | 2.43 | 0.41 |
| 47 | Mahismari | 171 | 219.51 | 0 | 0 | 202.50 | 4.05 | 12.96 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 48 | Jadubhitar Chhat | 153 | 64.80 | 0 | 0 | 40.50 | 0 | 24.30 |
| 49 | Damragayer Chhat | Incl. In 48 | 25.11 | NA | NA | NA | NA | NA |
| 50 | Mahatram | 121 | 141.35 | 0 | 0 | 134.46 | 6.48 | 0.41 |
| 51 | Udayasing | 228 | 256.77 | 0 | 0 | 243.00 | 0 | 13.77 |
| 52 | Shalbari Chhat, PartI | Incl. In 11 | 6.89 | NA | NA | NA | NA | NA |
| 53 | Dhukuria | 617 | 242.19 | 0 | 0 | 129.19 | 16.20 | 96.80 |
| 54 | Nichitpur | 487 | 168.08 | NA | NA | NA | NA | NA |
| 55 | Bania Khari | 175 | 172.13 | 0 | 0 | 88.70 | 10.53 | 72.90 |
| 56 | Guria | 316 | 155.52 | 0 | 0 | 80.19 | 8.10 | 67.23 |
| 57 | Nimai | 439 | 195.21 | 0 | 0 | 121.5 | 11.75 | 61.96 |
| 58 | Jugi Bhita | 527 | 208.58 | 0 | 0 | 121.5 | 11.75 | 75.33 |
| 59 | Panchkulguri | 196 | 181.85 | 0 | 0 | 113.81 | 8.50 | 59.54 |
| 60 | Gouri | Incl. In 15 | 107.73 | NA | NA | NA | NA | NA |
| 61 | Pataner Chhat | Incl. In 63 | 46.17 | NA | NA | NA | NA | NA |
| 75 | Kauakhali | 393 | 182.66 | 0 | 0 | 105.30 | 26.33 | 51.03 |
| 76 | Kalam | 124 | 195.21 | NA | NA | NA | NA | NA |
| 77 | Patiram | 663 | 196.43 | 0 | 0 | 153.90 | 16.20 | 26.33 |
| 78 | Tomba | 696 | 145.40 | 0 | 0 | 79.38 | 23.09 | 42.93 |
| 79 | Mathapari | 1705 | 206.15 | 0 | 0 | 35.24 | 33.61 | 137.30 |
| 80 | Matigara Hat | 2350 | 28.76 | 0 | 0 | 0 | 4.05 | 24.71 |
| 81 | Goucharan | 271 | 234.50 | 0 | 0 | 133.65 | 48.60 | 52.25 |
| 82 | Baragharia | 473 | 289.58 | 0 | 0 | 197.24 | 66.02 | 26.32 |
| 83 | Daknikata | 105 | 269.73 | 0 | 0 | 263.25 | 0 | 6.48 |
| 84 | Foutsingher Chhat | 941 | 23.49 | NA | NA | NA | NA | NA |
| 85 | Mandlaguri | 473 | 213.44 | 0 | 0 | 202.50 | 0 | 10.94 |
| 86 | Ujanu | 1194 | 223.97 | 0 | 0 | 182.25 | 4.05 | 37.67 |
| | Siliguri (MC) | 97484 | | | | | | |

P.S. KURSEONG

| JL.NO | VILLAGES/TOWN | POP | AREA | FRST | IRRI | UNIRR | CWST | |
|---|---|---|---|---|---|---|---|---|
| 13 | Makaibari T.G. | 1071 | 588.87 | NA | NA | NA | NA | NA |
| 14 | Punkhabari | | | | | | | |
| 15 | Longview T.G. | | 2162.30 | NA | NA | NA | NA | NA |
| 16 | Jamadar Bhitta Khasmahal | | | | | | | |
| 18 | Garidhura(Marionbari) T.G. | | | | | | | |
| 17 | Balasan Forest | - | 704.30 | NA | NA | NA | NA | NA |
| 19 | Saptiguri Khelaghar T.G. | - | 183.47 | NA | NA | NA | NA | NA |
| 20 | Pairi Kumari | 185 | 69.26 | 0.00 | 25..92 | 5.67 | 24.30 | 13.37 |
| 21 | Simulbari T.G. | 1547 | 688.91 | NA | NA | NA | NA | NA |
| 22 | Rakti Forest | - | 76.55 | NA | NA | NA | NA | NA |
| 23 | Baman Pokhri Forest | 173 | 550.80 | NA | NA | NA | NA | NA |
| 24 | Rohini T.G. | 1560 | 2119.77 | NA | NA | NA | NA | NA |
| 25 | Lama Gumba Forest | - | 205.74 | NA | NA | NA | NA. | NA |
| 26 | Selim Hill T.G. | 668 | 874.80 | 121.50 | 176.99 | 37.26 | 478.31 | 60.74 |
| 28 | Sukna Forest | 311 | 1551.96 | NA | NA | NA | NA | NA |
| 29 | Kanyan | - | 43.74 | NA | NA | NA | NA | NA |
| 30 | Sukna | 274 | 8.50 | 0.00 | 0.00 | 7.70 | 0.00 | 0.80 |
| 31 | Cart Road (N.C.) | 11440 | 1800.23 | 307.40 | 607.50 | 358.43 | 373.01 | 153.90 |
| 32 | Mahanadi Forest | - | 1881.23 | NA | NA | NA | NA | NA |
| | | | | | | | | |

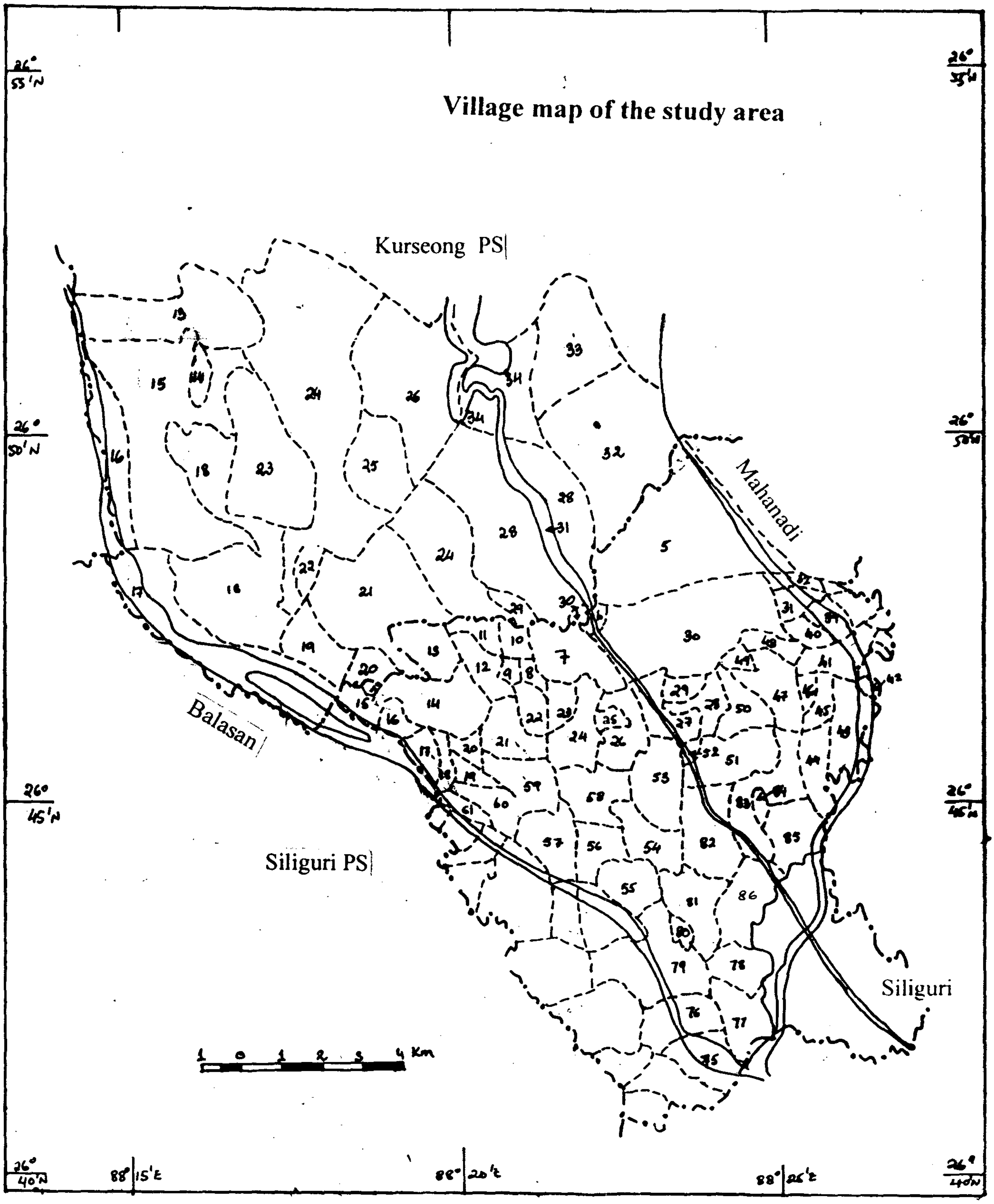
**LAND USE 1981**

P.S. SILIGURI

| JL.NO | VILL/ TOWN | POP | AREA | FOREST | IRRI | UNIRRI | CULT W | NAC |
|---|---|---|---|---|---|---|---|---|
| 5 | Mahanadi Forest | 793 | 1021.03 | 382.02 | 0 | 410.76 | 121.00 | 107.25 |
| 6 | Sukna, Part I | 1235 | 24.69 | 0 | 11.74 | 8.09 | 0 | 4.86 |
| 7 | Sukna Forest | 757 | 322.65 | 128.29 | 0 | 121.41 | 18.21 | 54.74 |
| 8 | Kamalabarir Chhat | 216 | 25.50 | 0 | 0 | 7.28 | 0 | 18.22 |
| 9 | Khoklong Chhat | 240 | 36.83 | 0 | 0 | 12.14 | 0 | 24.69 |
| 10 | Paharu | 55 | 70.010 | 0 | 0 | 25.90 | 0 | 44.11 |
| 11 | Chota Adalpur | 120 | 77.700 | 0 | 0 | 31.16 | 0 | 46.54 |
| 12 | Khoklong | 1019 | 119.380 | 0 | 0 | 40.47 | 0 | 78.91 |
| 13 | Bara Adalpur, Part II | 522 | 183.32 | 0 | 80.94 | 74.06 | 8.09 | 20.23 |
| 14 | Khaprail | 1428 | 451.63 | 0 | 40.47 | 170.78 | 199.92 | 40.46 |
| 15 | Patanjharer Chhat | 696 | 14.16 | 0 | 0 | 2.43 | 0 | 11.73 |
| 16 | Fulbari Chhat | 222 | 29.54 | 0 | 0 | 15.38 | 0 | 14.16 |
| 17 | Patan Chhat | 265 | 71.23 | 0 | 0 | 43.71 | 0 | 27.52 |
| 18 | Patan | 258 | 50.18 | 0 | 0 | 12.14 | 32.37 | 5.67 |
| 19 | Fulbari Pataner Chhat | 626 | 65.96 | 0 | 0 | 38.45 | 4.05 | 23.46 |
| 20 | Ruhinir Chhat | 1580 | 18.21 | 0 | 0 | 2.02 | 0 | 16.19 |
| 21 | Khopalasi | 1123 | 170.37 | 0 | 40.47 | 87.82 | 2.02 | 40.06 |
| 22 | Jhauguri | 997 | 88.22 | 0 | 0 | 69.61 | 2.02 | 16.59 |
| 23 | Jhauguri Chhat | 1349 | 77.30 | 0 | 0 | 55.44 | 9.31 | 12.55 |
| 24 | Rajpairi | 771 | 210.44 | 0 | 80.94 | 80.94 | 20.23 | 28.33 |
| 25 | Chamtaguri Chhat | 67 | 19.02 | 0 | 0 | 15.78 | 0 | 3.24 |
| 26 | Chamta | 1091 | 193.44 | 0 | 80.94 | 85.39 | 14.16 | 12.95 |
| 27 | Panchanai | 1320 | 135.97 | 0 | 60.70 | 64.75 | 2.02 | 8.50 |
| 28 | Nunu Bairagi | 1282 | 120.60 | 0 | 0 | 63.94 | 0 | 56.66 |
| 29 | Nunu Bairagi Chhat | 369 | 74.46 | 0 | 0 | 38.04 | 0 | 36.42 |
| 30 | Mohargong T.E. | 3942 | 854.30 | 0 | 0 | 630.50 | 20.23 | 203.57 |
| 31 | Purba Karaibarir Chhat | 796 | 49.78 | 0 | 0 | 20.65 | 8.93 | 20.23 |
| 32 | Gulmakhari | 402 | 63.13 | 0 | 0 | 22.66 | 14.16 | 26.31 |
| 39 | Karaibari | 702 | 158.64 | 0 | 16.59 | 133.95 | 0 | 8.10 |
| 40 | Dariagramer Chhat | 1086 | 7.69 | 0 | 0 | 4.05 | 0 | 3.64 |
| 41 | Shishabari | 661 | 127.07 | 0 | 40.47 | 74.46 | 0 | 12.14 |
| 42 | Rupan Chhat | 38 | 2.43 | 0 | 0 | 1.62 | 0 | 0.81 |
| 43 | Palash | 721 | 221.77 | 0 | 0 | 214.48 | 0 | 7.29 |
| 44 | Kalkut | 862 | 148.12 | 0 | 0 | 125.45 | 2.02 | 20.65 |
| 45 | Kalabari | 531 | 77.70 | 0 | 0 | 58.68 | 0 | 19.02 |
| 46 | Malahar | 388 | 35.21 | 0 | 0 | 28.33 | 0 | 6.88 |
| 47 | Mahismari | 867 | 218.94 | 0 | 0 | 194.25 | 0 | 24.69 |
| 48 | Jadubhitar Chhat | 223 | 64.75 | 0 | 0 | 36.43 | 8.09 | 20.23 |
| 49 | Damragayer Chhat | 116 | 25.09 | 0 | 0 | 12.55 | 4.05 | 8.49 |
| 50 | Mahatram | 1761 | 139.62 | 0 | 0 | 101.17 | 12.14 | 26.31 |
| 51 | Udayasing | 772 | 256.98 | 0 | 40.47 | 183.73 | 2.43 | 30.35 |
| 52 | Shalbari Chhat, PartI | 484 | 6.88 | 0 | 0 | 4.05 | 0 | 2.83 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 53 | Dhukuria | 1178 | 242.00 | 0 | 40.47 | 144.57 | 16.19 | 40.87 |
| 54 | Nichitpur | 457 | 167.95 | 0 | 0 | 143.66 | 2.02 | 22.27 |
| 55 | Bania Khari | 1214 | 171.99 | 0 | 80.94 | 60.70 | 12.14 | 18.21 |
| 56 | Guria | 674 | 155.00 | 0 | 20.23 | 101.17 | 4.05 | 29.55 |
| 57 | Nimai | 872 | 198.70 | 0 | 60.70 | 72.03 | 24.28 | 41.69 |
| 58 | Jugi Bhita | 915 | 208.41 | 0 | 91.05 | 51.80 | 40.47 | 25.09 |
| 59 | Panchkulguri | 328 | 181.70 | 0 | 101.70 | 60.70 | 6.07 | 13.23 |
| 60 | Gouri | 705 | 107.65 | 0 | 0 | 65.15 | 0 | 42.50 |
| 61 | Pataner Chhat | - | 46.13 | 0 | 0 | 33.99 | 2.43 | 9.71 |
| 75 | Kauakhali | 1523 | ,182.11 | 0 | 0 | 104.94 | 26.42 | 50.75 |
| 76 | Kalam | 211 | 195.06 | 0 | 0 | 104.00 | 60.70 | 30.36 |
| 77 | Patiram | 1586 | 180.89 | 0 | 23.07 | 141.64 | 0 | 16.18 |
| 78 | Tomba | 770 | 146.50 | 0 | 40.47 | 93.89 | 4.05 | 8.09 |
| 79 | Mathapari | 2536 | 209.63 | 0 | 0 | 135.57 | 6.07 | 67.99 |
| 80 | Matigara Hat | 1843 | 28.73 | 0 | 0 | 20.64 | 0 | 8.09 |
| 81 | Goucharan | 1502 | 234.31 | 0 | 121.41 | 60.70 | 20.23 | 31.97 |
| 82 | Baragharia | 1461 | 289.76 | 0 | 60.70 | 161.87 | 26.71 | 40.48 |
| 83 | Daknikata | 1025 | 269.52 | 0 | 20.23 | 156.21 | 24.28 | 68.80 |
| 84 | Foutsingher Chhat | 1142 | 23.47 | 0 | 0 | 17.62 | 0 | 5.85 |
| 85 | Mandlaguri | 1067 | 214.48 | 0 | 40.47 | 131.52 | 4.05 | 38.44 |
| 86 | Ujanu | 4398 | 224.20 | 0 | 101.17 | 40.47 | 5.67 | 76.89 |
| | Siliguri (MC) | 154378 | | | | | | |
| | | | | | | | | |

| JL. NO | VILLAGES/TOWN | POP | AREA | FRST | IRRI | UNIRR | CWST | NAC |
|---|---|---|---|---|---|---|---|---|
| 13 | Makaibari T.G. | 1156 | 611.89 | 0 | 141.64 | 384.45 | 4.86 | 80.94 |
| 14 | Punkhabari | | | | | | | |
| 15 | Longview T.G. | | 2072.42 | 102.79 | 357.34 | 1025.89 | 188.18 | 398.22 |
| 16 | Jamadar Bhitta Khasmahal | | | | | | | |
| 18 | Garidhura(Marionbari) T.G. | | | | | | | |
| 17 | Balasan Forest | - | 703.75 | 133.95 | 0 | 384.05 | 117.36 | 68.39 |
| 19 | Saptiguri Khelaghar T.G. | 330 | 836.49 | 161.87 | 80.94 | 451.23 | 21.04 | 121.41 |
| 20 | Pairi Kumari | 207 | 60.30 | 0 | 3.24 | 52.20 | 0.81 | 4.05 |
| 21 | Simulbari T.G. | 1396 | 743.82 | 205.58 | 0 | 317.27 | 6.88 | 204.09 |
| 22 | Rakti Forest | - | 76.49 | 30.76 | 0 | 23.88 | 6.48 | 15.37 |
| 23 | Baman Pokhri Forest | 202 | 550.38 | 157.02 | 0 | 299.47 | 68.80 | 25.09 |
| 24 | Rohini T.G. | 1444 | 2037.21 | 122.22 | 202.34 | 1394.96 | 202.34 | 115.35 |
| 25 | Lama Gumba Forest | 5 | 205.58 | 108.86 | 0 | 29.14 | 62.73 | 4.85 |
| 26 | Selim Hill T.G. | 875 | 871.30 | 119.38 | 202.34 | 141.64 | 323.75 | 84.19 |
| 28 | Sukna Forest | 349 | 1550.77 | 779.83 | 0 | 404.28 | 309.99 | 56.67 |
| 29 | Kanyan | - | 43.71 | 13.76 | 0 | 16.19 | 6.07 | 8.09 |
| 30 | Sukna | 389 | 8.50 | 0 | 0 | 2.43 | 0 | 6.07 |
| 31 | Cart Road (N.C.) | 11038 | 1799.00 | NA | NA | NA | NA | NA |
| 32 | Mahanadi Forest | - | 1819.78 | 890.32 | 0 | 677.85 | 238.77 | 12.84 |




**Village map of the study area**

Appendix ii

**LAND USE PERCENTAGES (1971)**
**P.S. SILIGURI**

| JL. NO | VILLAGES | POP | AREA | FOREST | IRRI. | UNIRRI | CULT W. | NAC |
|---|---|---|---|---|---|---|---|---|
| 5 | Mahanadi Forest | 159 | 1021.82 | NA | NA | NA | NA | NA |
| 6 | Sukna, Part I | 1933 | 25.11 | - | - | 100.00 | - | - |
| 7 | Sukna Forest | - | 332.91 | NA | NA | NA | NA | NA |
| 8 | Kamalabarir Chhat | Incl. in 9 | 25.52 | NA | NA | NA | NA | NA |
| 9 | Khoklong Chhat | 660 | 36.86 | - | - | 43.95 | - | 56.05 |
| 10 | Paharu | Incl. In 11 | 70.07 | NA | NA | NA | NA | NA |
| 11 | Chota Adalpur | 320 | 77.76 | NA | NA | NA | NA | NA |
| 12 | Khoklong | 914 | 119.48 | NA | NA | NA | NA | NA |
| 13 | Bara Adalpur, Part II | 83 | 183.47 | NA | NA | NA | NA | NA |
| 14 | Khaprail | 339 | 449.96 | - | - | 54.90 | 3.69 | 41.40 |
| 15 | Patanjharer Chhat | 1091 | 14.18 | NA | NA | NA | NA | NA |
| 16 | Fulbari Chhat | 564 | 29.57 | NA | NA | NA | NA | NA |
| 17 | Patan Chhat | Incl. In 15 | 71.28 | NA | NA | NA | NA | NA |
| 18 | Patan | Incl. In 15 | 50.22 | NA | NA | NA | NA | NA |
| 19 | Fulbari Pataner Chhat | Incl. In 16 | 66.02 | NA | NA | NA | NA | NA |
| 20 | Ruhinir Chhat | 965 | 18.23 | NA | NA | NA | NA | NA |
| 21 | Khopalasi | 722 | 170.51 | - | 0.95 | 62.71 | 5.94 | 30.40 |
| 22 | Jhauguri | 234 | 88.29 | - | - | 65.13 | 13.31 | 21.56 |
| 23 | Jhauguri Chhat | 69 | 77.36 | NA | NA | NA | NA | NA |
| 24 | Rajpairi | 505 | 210.20 | - | - | 53.76 | 13.87 | 32.37 |
| 25 | Chamtaguri Chhat | 47 | 19.05 | - | - | 44.67 | 19.16 | 36.17 |
| 26 | Chamta | 458 | 193.19 | - | - | 61.21 | 8.14 | 30.61 |
| 27 | Panchanai | 499 | 135.27 | - | - | 44.91 | 47.90 | 7.19 |
| 28 | Nunu Bairagi | 697 | 104.49 | NA | NA | NA | NA | NA |
| 29 | Nunu Bairagi Chhat | Incl. In 6 | 74.52 | NA | NA | NA | NA | NA |
| 30 | Mohargong T.E. | 2238 | 856.58 | - | - | 69.03 | 32.36 | 28.61 |
| 31 | Purba Karaibarir Chhat | Incl. In 30 | 49.82 | NA | NA | NA | NA | NA |
| 32 | Gulmakhari | Incl. In 30 | 63.18 | NA | NA | NA | NA | NA |
| 39 | Karaibari | 221 | 158.76 | - | - | 76.53 | 10.20 | 13.27 |
| 40 | Dariagramer Chhat | 1644 | 7.70 | - | - | 47.40 | - | 52.60 |
| 41 | Shishabari | 470 | 127.17 | - | - | 85.99 | - | 14.01 |
| 42 | Rupan Chhat | 50 | 2.43 | - | - | 83.54 | - | 16.46 |
| 43 | Palash | 619 | 221.54 | - | - | 91.41 | 3.84 | 4.75 |
| 44 | Kalkut | 274 | 145.8 | - | - | 83.34 | 8.33 | 8.33 |
| 45 | Kalabari | 425 | 77.76 | - | - | 98.96 | - | 1.04 |
| 46 | Malahar | 66 | 35.24 | - | - | 91.94 | 6.90 | 1.16 |
| 47 | Mahismari | 171 | 219.51 | - | - | 92.25 | 1.85 | 5.90 |
| 48 | Jadubhitar Chhat | 153 | 64.80 | - | - | 62.50 | - | 37.50 |
| 49 | Damragayer Chhat | Incl. In 48 | 25.11 | NA | NA | NA | NA | NA |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 50 | Mahatram | 121 | 141.35 | - | - | 95.13 | 4.58 | 0.29 |
| 51 | Udayasing | 228 | 256.77 | - | - | 94.64 | - | 5.36 |
| 52 | Shalbari Chhat, PartI | Incl. In 11 | 6.89 | NA | NA | NA | NA | NA |
| 53 | Dhukuria | 617 | 242.19 | - | - | 53.34 | 6.69 | 39.97 |
| 54 | Nichitpur | 487 | 168.08 | NA | NA | NA | NA | NA |
| 55 | Bania Khari | 175 | 172.13 | - | - | 51.53 | 6.12 | 42.35 |
| 56 | Guria | 316 | 155.52 | - | - | 51.56 | 5.21 | 43.23 |
| 57 | Nimai | 439 | 195.21 | - | - | 62.24 | 6.02 | 31.74 |
| 58 | Jugi Bhita | 527 | 208.58 | - | - | 58.25 | 5.63 | 36.12 |
| 59 | Panchkulguri | 196 | 181.85 | - | - | 62.58 | 4.67 | 32.74 |
| 60 | Gouri | Incl. In 15 | 107.73 | NA | NA | NA | NA | NA |
| 61 | Pataner Chhat | Incl. In 63 | 46.17 | NA | NA | NA | NA | NA |
| 75 | Kauakhali | 393 | 182.66 | - | - | 57.65 | 14.41 | 27.94 |
| 76 | Kalam | 124 | 195.21 | NA | NA | NA | NA | NA |
| 77 | Patiram | 663 | 196.43 | - | - | 78.35 | 8.25 | 13.40 |
| 78 | Tomba | 696 | 145.40 | - | - | 54.58 | 15.87 | 29.55 |
| 79 | Mathapari | 1705 | 206.15 | - | - | 17.10 | 16.30 | 66.60 |
| 80 | Matigara Hat | 2350 | 28.76 | - | - | - | 14.08 | 85.92 |
| 81 | Goucharan | 271 | 234.50 | - | - | 56.99 | 20.73 | 22.28 |
| 82 | Baragharia | 473 | 289.58 | - | - | 68.11 | 22.80 | 9.09 |
| 83 | Daknikata | 105 | 269.73 | - | - | 97.60 | - | 2.40 |
| 84 | Foutsingher Chhat | 941 | 23.49 | NA | NA | NA | NA | NA |
| 85 | Mandlaguri | 473 | 213.44 | - | - | 94.87 | - | 5.13 |
| 86 | Ujanu | 1194 | 223.97 | - | - | 81.37 | 1.81 | 16.82 |
| | Siliguri (MC) | 97484 | | | | | | |

P.S. KURSEONG

| JL.NO | VILLAGES/TOWN | POP | AREA | FRST | IRRI | UNIRR | CWST | |
|---|---|---|---|---|---|---|---|---|
| 13 | Makaibari T.G. | 1071 | 588.87 | NA | NA | NA | NA | NA |
| 14 | Punkhabari | | | | | | | |
| 15 | Longview T.G. | | 2162.30 | NA | NA | NA | NA | NA |
| 16 | Jamadar Bhitta Khasmahal | | | | | | | |
| 18 | Garidhura(Marionbari) T.G. | | | | | | | |
| 17 | Balasan Forest | - | 704.30 | NA | NA | NA | NA | NA |
| 19 | Saptiguri Khelaghar T.G. | - | 183.47 | NA | NA | NA | NA | NA |
| 20 | Pairi Kumari | 185 | 69.26 | - | 37.42 | 8.19 | 35.09 | 19.30 |
| 21 | Simulbari T.G. | 1547 | 688.91 | NA | NA | NA | NA | NA |
| 22 | Rakti Forest | - | 76.55 | NA | NA | NA | NA | NA |
| 23 | Baman Pokhri Forest | 173 | 550.80 | NA | NA | NA | NA | NA |
| 24 | Rohini T.G. | 1560 | 2119.77 | NA | NA | NA | NA | NA |
| 25 | Lama Gumba Forest | - | 205.74 | NA | NA | NA | NA | NA |
| 26 | Selim Hill T.G. | 668 | 874.80 | 13.89 | 20.23 | 4.26 | 54.68 | 6.94 |
| 28 | Sukna Forest | 311 | 1551.96 | NA | NA | NA | NA | NA |
| 29 | Kanyan | - | 43.74 | NA | NA | NA | NA | NA |
| 30 | Sukna | 274 | 8.50 | - | - | 90.59 | - | 9.41 |
| 31 | Cart Road (N.C.) | 11440 | 1800.23 | 17.08 | 33.75 | 19.90 | 20.72 | 8.55 |
| 32 | Mahanadi Forest | - | 1881.23 | NA | NA | NA | NA | NA |

**LAND USE PERCENTAGES (1981)**

**SILIGURI**

| JL.NO | VILL/ TOWN | POP | AREA | FOREST | IRRI | UNIRRI | CULT W | NAC |
|---|---|---|---|---|---|---|---|---|
| 5 | Mahanadi Forest | 793 | 1021.03 | 37.42 | - | 40.23 | 11.85 | 10.50 |
| 6 | Sukna, Part I | 1235 | 24.69 | - | 47.55 | 32.77 | - | 19.68 |
| 7 | Sukna Forest | 757 | 322.65 | 39.76 | - | 37.63 | 5.64 | 16.97 |
| 8 | Kamalabarir Chhat | 216 | 25.50 | - | - | 28.55 | - | 71.45 |
| 9 | Khoklong Chhat | 240 | 36.83 | - | - | 32.96 | - | 67.04 |
| 10 | Paharu | 55 | 70.010 | - | - | 36.99 | - | 63.01 |
| 11 | Chota Adalpur | 120 | 77.700 | - | - | 40.10 | - | 59.90 |
| 12 | Khoklong | 1019 | 119.380 | - | - | 33.90 | - | 66.10 |
| 13 | Bara Adalpur, Part II | 522 | 183.32 | - | 44.15 | 40.40 | 4.41 | 11.04 |
| 14 | Khaprail | 1428 | 451.63 | - | 8.96 | 37.81 | 44.27 | 8.96 |
| 15 | Patanjharer Chhat | 696 | 14.16 | - | - | 17.16 | - | 82.83 |
| 16 | Fulbari Chhat | 222 | 29.54 | - | - | 52.06 | - | 47.94 |
| 17 | Patan Chhat | 265 | 71.23 | - | - | 61.36 | - | 38.64 |
| 18 | Patan | 258 | 50.18 | - | - | 24.19 | 64.51 | 11.30 |
| 19 | Fulbari Pataner Chhat | .626 | 65.96 | - | - | 58.29 | .6.14 | 35.57 |
| 20 | Ruhinir Chhat | 1580 | 18.21 | - | - | 11.09 | - | 88.91 |
| 21 | Khopalasi | 1123 | 170.37 | - | 23.75 | 51.55 | 1.19 | 23.51 |
| 22 | Jhauguri | 997 | 88.22 | - | - | 78.91 | 2.29 | 18.80 |
| 23 | Jhauguri Chhat | 1349 | 77.30 | - | - | 71.72 | 12.04 | 16.24 |
| 24 | Rajpairi | 771 | 210.44 | - | 38.46 | 38.46 | 9.62 | 13.46 |
| 25 | Chamtaguri Chhat | 67 | 19.02 | - | - | 82.97 | - | 17.03 |
| 26 | Chamta | 1091 | 193.44 | - | 41.84 | 44.14 | 7.33 | 6.69 |
| 27 | Panchanai | 1320 | 135.97 | - | 44.64 | 47.62 | 1.49 | 6.25 |
| 28 | Nunu Bairagi | 1282 | 120.60 | - | - | 53.02 | - | 46.98 |
| 29 | Nunu Bairagi Chhat | 369 | 74.46 | - | - | 51.09 | - | 48.91 |
| 30 | Mohargong T.E. | 3942 | 854.30 | - | - | 73.80 | 2.37 | 23.83 |
| 31 | Purba Karaibarir Chhat | 796 | 49.78 | - | - | 41.46 | 17.92 | 40.62 |
| 32 | Gulmakhari | 402 | 63.13 | - | - | 35.89 | 22.43 | 41.68 |
| 39 | Karaibari | 702 | 158.64 | - | 10.46 | 84.44 | - | 5.10 |
| 40 | Dariagramer Chhat | 1086 | 7.69 | - | - | 52.76 | - | 47.33 |
| 41 | Shishabari | 661 | 127.07 | - | 31.85 | 58.60 | - | 9.55 |
| 42 | Rupan Chhat | 38 | 2.43 | - | - | 66.67 | - | 33.33 |
| 43 | Palash | 721 | 221.77 | - | - | 96.71 | - | 3.29 |
| 44 | Kalkut | 862 | 148.12 | - | - | 84.69 | 1.36 | 13.94 |
| 45 | Kalabari | 531 | 77.70 | - | - | 75.52 | - | 24.48 |
| 46 | Malahar | 388 | 35.21 | - | - | 80.46 | - | 19.54 |
| 47 | Mahismari | 867 | 218.94 | - | - | 88.72 | - | 11.28 |
| 48 | Jadubhitar Chhat | 223 | 64.75 | - | - | 56.26 | 12.49 | 31.24 |
| 49 | Damragayer Chhat | 116 | 25.09 | - | - | 50.02 | 16.14 | 33.84 |
| 50 | Mahatram | 1761 | 139.62 | - | - | 72.46 | 8.70 | 18.84 |
| 51 | Udayasing | 772 | 256.98 | - | 15.75 | 71.50 | 0.95 | 11.80 |
| 52 | Shalbari Chhat, PartI | 484 | 6.88 | - | - | 58.87 | - | 41.13 |
| 53 | Dhukuria | 1178 | 242.00 | - | 16.72 | 59.71 | 6.69 | 16.88 |
| 54 | Nichitpur | 457 | 167.95 | - | - | 85.54 | 1.20 | 13.26 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 55 | Bania Khari | 1214 | 171.99 | - | 47.06 | 35.29 | 7.06 | 10.59 |
| 56 | Guria | 674 | 155.00 | - | 13.05 | 65.27 | 2.62 | 19.06 |
| 57 | Nimai | 872 | 198.70 | - | 30.55 | 36.25 | 12.22 | 20.98 |
| 58 | Jugi Bhita | 915 | 208.41 | - | 43.69 | 24.85 | 19.42 | 12.04 |
| 59 | Panchkulguri | 328 | 181.70 | - | 55.97 | 33.40 | 3.34 | 7.28 |
| 60 | Gouri | 705 | 107.65 | - | - | 60.52 | - | 39.48 |
| 61 | Pataner Chhat | - | 46.13 | - | - | 73.68 | 5.27 | 21.05 |
| 75 | Kauakhali | 1523 | 182.11 | - | - | 57.62 | 14.51 | 27.87 |
| 76 | Kalam | 211 | 195.06 | - | - | 53.32 | 31.32 | 15.56 |
| 77 | Patiram | 1586 | 180.89 | - | 12.75 | 78.30 | - | 8.95 |
| 78 | Tomba | 770 | 146.50 | - | 27.62 | 64.09 | 2.76 | 5.52 |
| 79 | Mathapari | 2536 | 209.63 | - | - | 64.67 | 2.90 | 32.43 |
| 80 | Matigara Hat | 1843 | 28.73 | - | - | 71.84 | - | 28.16 |
| 81 | Goucharan | 1502 | 234.31 | - | 51.82 | 25.91 | 8.63 | 13.64 |
| 82 | Baragharia | 1461 | 289.76 | - | 20.95 | 55.86 | 9.22 | 13.97 |
| 83 | Daknikata | 1025 | 269.52 | - | 7.50 | 57.96 | 9.01 | 25.53 |
| 84 | Foutsingher Chhat | 1142 | 23.47 | - | - | 75.07 | - | 24.93 |
| 85 | Mandlaguri | 1067 | 214.48 | - | 18.87 | 61.32 | 1.89 | 17.92 |
| 86 | Ujanu | 4398 | 224.20 | - | 45.12 | 18.05 | 2.53 | 34.30 |
| | Siliguri (MC) | 154378 | | | | | | |
| | | | | | | | | |

**KURSEONG**

| JL. NO | VILLAGES/TOWN | POP | AREA | FRST | IRRI | UNIRR | CWST | NAC |
|---|---|---|---|---|---|---|---|---|
| 13 | Makaibari T.G. | 1156 | 611.89 | - | 23.15 | 62.83 | 0.79 | 13.23 |
| 14 | Punkhabari | | | | | | | |
| 15 | Longview T.G. | | 2072.42 | 4.96 | 17.24 | 49.50 | 9.08 | 19.22 |
| 16 | Jamadar Bhitta Khasmahal | | | | | | | |
| 18 | Garidhura(Marionbari) T.G. | | | | | | | |
| 17 | Balasan Forest | - | 703.75 | 19.03 | - | 54.57 | 16.68 | 9.72 |
| 19 | Saptiguri Khelaghar T.G. | 330 | 836.49 | 19.35 | 9.68 | 53.94 | 2.52 | 14.51 |
| 20 | Pairi Kumari | 207 | 60.30 | - | 5.73 | 86.57 | 1.34 | 6.72 |
| 21 | Simulbari T.G. | 1396 | 743.82 | 27.64 | - | 42.65 | 0.92 | 28.78 |
| 22 | Rakti Forest | - | 76.49 | 41.21 | - | 31.22 | 8.47 | 20.09 |
| 23 | Baman Pokhri Forest | 202 | 550.38 | 28.52 | - | 54.41 | 12.50 | 4.56 |
| 24 | Rohini T.G. | 1444 | 2037.21 | 6.0 | 9.93 | 68.47 | 9.93 | 5.66 |
| 25 | Lama Gumba Forest | 5 | 205.58 | 52.95 | - | 14.17 | 30.51 | 2.36 |
| 26 | Selim Hill T.G. | 875 | 871.30 | 13.70 | 23.22 | 16.26 | 37.16 | 9.66 |
| 28 | Sukna Forest | 349 | 1550.77 | 50.29 | - | 26.07 | 19.99 | 3.65 |
| 29 | Kanyan | - | 43.71 | 31.48 | - | 37.04 | 13.89 | 18.51 |
| 30 | Sukna | 389 | 8.50 | - | - | 28.59 | - | 71.41 |
| 31 | Cart Road (N.C.) | 11038 | 1799.00 | NA | NA | NA | NA | NA |
| 32 | Mahanadi Forest | - | 1819.78 | 48.92 | - | 37.25 | 13.12 | 0.71 |
| | | | | | | | | |

# Appendix iii

**GROWTH IN POPULATION DENSITY**

| JL. NO | VILL/ TOWN | Pop '71 | Pop '81 | Pop '91 | PD '71 | PD '81 | PD '91 | % growth 71-81 | % growth 81-91 |
|---|---|---|---|---|---|---|---|---|---|
| 5 | Mahanadi Forest | 159 | 793 | 502 | 0.16 | 0.78 | 0.49 | 387.5 | -37.18 |
| 6 | Sukna, Part I | 1933 | 1235 | 1576 | 76.98 | 52.45 | 63.83 | -25.42 | 11.93 |
| 7 | Sukna Forest | - | 757 | - | - | 2.35 | - | - | -100.00 |
| 8 | Kamalabarir Chhat | Incl. in 9 | 216 | 207 | - | 25.69 | 8.12 | 198.20 | -44.66 |
| 9 | Khoklong Chhat | 660 | 240 | 344 | 10.58 | 5.86 | 9.34 | | |
| 10 | Paharu | Incl. In 11 | 55 | - | - | 0.79 | - | 7.87 | -100.00 |
| 11 | Chota Adalpur | 320 | 120 | - | 2.16 | 1.54 | - | | |
| 12 | Khoklong | 914 | 1019 | 1275 | 7.65 | 8.54 | 10.68 | 11.63 | 25.06 |
| 13 | Bara Adalpur, Part II | 83 | 522 | 677 | 0.45 | 2.85 | 3.69 | 533.33 | 29.47 |
| 14 | Khaprail | 339 | 1428 | 2402 | 0.75 | 3.16 | 5.32 | 321.33 | 60.35 |
| 15 | Patanjharer Chhat | 1091 | 696 | 825 | 76.94 | 49.15 | 58.26 | -16.09 | -4.77 |
| 16 | Fulbari Chhat | 564 | 222 | - | 19.07 | 7.52 | - | -10.80 | -100.00 |
| 17 | Patan Chhat | Incl. In 15 | 265 | - | - | 3.72 | - | | |
| 18 | Patan | Incl. In 15 | 258 | - | - | 5.14 | - | | |
| 19 | Fulbari Pataner Chhat | Incl. In 16 | 626 | 151 | - | 9.49 | 2.29 | | |
| 20 | Ruhinir Chhat | 965 | 1580 | 1917 | 52.93 | 86.77 | 105.27 | 63.93 | 21.32 |
| 21 | Khopalasi | 722 | 1123 | 633 | 4.23 | 6.59 | 3.72 | 55.79 | -43.55 |
| 22 | Jhauguri | 234 | 997 | 354 | 2.65 | 11.30 | 4.01 | 326.42 | -64.51 |
| 23 | Jhauguri Chhat | 69 | 1349 | 1770 | 0.89 | 17.45 | 22.90 | 1860.67 | 31.23 |
| 24 | Rajpairi | 505 | 771 | 994 | 2.40 | 3.66 | 4.72 | 52.50 | 28.96 |
| 25 | Chamtaguri Chhat | 47 | 67 | 382 | 2.47 | 2.52 | 20.08 | 42.51 | 470.45 |
| 26 | Chamta | 458 | 1091 | 1060 | 2.37 | 5.64 | 5.48 | 137.97 | -2.84 |
| 27 | Panchanai | 499 | 1320 | 1257 | 3.69 | 9.71 | 9.24 | 163.14 | -4.84 |
| 28 | Nunu Bairagi | 697 | 1282 | 1088 | 6.67 | 10.63 | 9.02 | 59.37 | -15.15 |
| 29 | Nunu Bairagi Chhat | Incl. In 6 | 369 | 32 | - | 4.96 | 0.43 | | |
| 30 | Mohargong T.E. | 2238 | 3942 | 1801 | 2.61 | 4.61 | 2.11 | | |
| 31 | Purba Karaibarir Chhat | Incl. In 30 | 796 | - | - | 15.99 | - | 933.33 | -77.98 |
| 32 | Gulmakhari | Incl. In 30 | 402 | 242 | - | 6.37 | 3.83 | | |
| 39 | Karaibari | 221 | 702 | 765 | 1.39 | 4.43 | 4.82 | 218.71 | 8.80 |
| 40 | Dariagramer Chhat | 1644 | 1086 | - | 213.51 | 134.72 | - | -36.90 | -100.00 |
| 41 | Shishabari | 470 | 661 | 441 | 3.70 | 5.20 | 3.47 | 40.54 | -33.27 |
| 42 | Rupan Chhat | 50 | 38 | 19 | 20.58 | 15.64 | 7.82 | -24.00 | -50.00 |
| 43 | Palash | 619 | 721 | 1052 | 2.79 | 3.25 | 4.74 | 16.49 | 45.85 |
| 44 | Kalkut | 274 | 862 | 1278 | 1.88 | 5.82 | 8.63 | 209.57 | 48.28 |
| 45 | Kalabari | 425 | 531 | 575 | 5,47 | 6.83 | 7.40 | 24.86 | 8.35 |
| 46 | Malahar | 66 | 388 | 451 | 1.87 | 11.02 | 12.81 | 489.30 | 16.24 |
| 47 | Mahismari | 171 | 867 | 831 | 0.78 | 3.96 | 3.80 | 407.69 | -4.04 |
| 48 | Jadubhitar Chhat | 153 | 223 | 445 | 2.36 | 3.44 | 6.87 | 45.76 | 99.71 |
| 49 | Damragayer Chhat | Incl. In 48 | 116 | 1164 | - | 4.62 | 46.39 | | 904.11 |
| 50 | Mahatram | 121 | 1761 | 1767 | 0.86 | 12.61 | 12.66 | 1366.30 | 0.40 |
| 51 | Udayasing | 228 | 772 | 1038 | 0.89 | 3.00 | 4.04 | 237.08 | 34.67 |
| 52 | Shalbari Chhat, PartI | Incl. In 11 | 484 | 257 | - | 70.34 | 37.35 | | -46.90 |
| 53 | Dhukuria | 617 | 1178 | 1275 | 2.55 | 4.87 | 5.27 | 90.98 | 8.21 |
| 54 | Nichitpur | 487 | 457 | 542 | 3.90 | 2.72 | 3.23 | -30.26 | 18.75 |
| 55 | Bania Khari | 175 | 1214 | 1984 | 1.02 | 7.06 | 11.54 | 592.16 | 63.46 |
| 56 | Guria | 316 | 674 | 1547 | 2.03 | 4.35 | 9.98 | 114.29 | 129.46 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 57 | Nimai | 439 | 872 | 1349 | 2.25 | 4.39 | 6.79 | 95.11 | 54.76 |
| 58 | Jugi Bhita | 527 | 915 | 942 | 2.52 | 4.39 | 4.52 | 74.21 | 2.96 |
| 59 | Panchkulguri | 196 | 328 | 814 | 1.08 | 1.81 | 4.48 | 67.59 | 147.51 |
| | | | | | | | | | |
| 60 | Gouri | Incl. In 15 | 705 | 347 | - | 6.55 | 3.22 | | |
| 61 | Pataner Chhat | Incl. In 63 | - | - | - | - | - | - | - |
| 75 | Kauakhali | 393 | 1523 | 1838 | 2.15 | 8.36 | 10.09 | 288.84 | 20.69 |
| 76 | Kalam | 124 | 211 | 528 | 0.64 | 1.08 | 2.71 | 68.75 | 150.93 |
| 77 | Patiram | 663 | 1586 | 2450 | 3.38 | 8.77 | 13.54 | 159.47 | 54.39 |
| 78 | Tomba | 696 | 770 | 1874 | 4.79 | 5.26 | 12.79 | 9.81 | 143.16 |
| 79 | Mathapari | 1705 | 2536 | 3144 | 8.27 | 12.10 | 15.00 | 46.31 | 23.97 |
| 80 | Matigara Hat | 2350 | 1843 | 1990 | 81.71 | 64.15 | 69.27 | -21.49 | 7.98 |
| 81 | Goucharan | 271 | 1502 | 1054 | 1.16 | 6.41 | 4.50 | 452.59 | -29.80 |
| 82 | Baragharia | 473 | 1461 | 1393 | 1.63 | 5.04 | 4.81 | 209.20 | -11.71 |
| 83 | Daknikata | 105 | 1025 | 1321 | 0.39 | 8.80 | 4.90 | 2156.41 | -44.32 |
| 84 | Foutsingher Chhat | 941 | 1142 | 440 | 40.06 | 48.65 | 18.75 | 21.44 | -61.46 |
| 85 | Mandlaguri | 473 | 1067 | 6797 | 2.22 | 4.97 | 31.69 | 123.87 | 537.63 |
| 86 | Ujanu | 1194 | 4398 | 2929 | 5.33 | 19.62 | 13.06 | 268.11 | -33.44 |
| | Siliguri (MC) | 97484 | 154378 | | | | | | |
| **KURSEONG** | | | | | | | | | |
| 13 | Makaibari T.G. | 1071 | 1156 | 1555 | 1.82 | 1.89 | 2.54 | 3.85 | 34.39 |
| 14 | Punkhabari | | | | | | | | |
| 15 | Longview T.G. | | | | 2.16 | 2.18 | 4.16 | 0.93 | 90.83 |
| 16 | Jamadar Bhitta Khasmahal | | | | | | | | |
| 18 | Garidhura(Marionbari) T.G. | | | | | | | | |
| 17 | Balasan Forest | - | - | - | - | - | - | - | - |
| 19 | Saptiguri Khelaghar T.G. | - | 330 | 407 | - | 0.39 | 0.49 | | 25.64 |
| 20 | Pairi Kumari | 185 | 207 | 229 | 2.67 | 3.43 | 3.80 | 28.46 | 10.79 |
| 21 | Simulbari T.G. | 1547 | 1396 | 2744 | 2.25 | 1.88 | 3.69 | -16.44 | 96.28 |
| 22 | Rakti Forest | - | - | - | - | - | - | - | - |
| 23 | Baman Pokhri Forest | 173 | 202 | 262 | 0.31 | 0.37 | 0.48 | 19.35 | 29.73 |
| 24 | Rohini T.G. | 1560 | 1444 | 1909 | 0.74 | 0.71 | 0.94 | -4.05 | 32.39 |
| 25 | Lama Gumba Forest | - | 5 | 19 | - | 0.02 | 0.09 | | 350.00 |
| 26 | Selim Hill T.G. | 668 | 875 | 621 | 0.76 | 1.00 | 0.71 | 31.58 | -29.00 |
| 28 | Sukna Forest | 311 | 349 | 4467 | 0.20 | 0.23 | 2.88 | 15.00 | 1152.17 |
| 29 | Kanyan | - | - | - | - | - | - | - | - |
| 30 | Sukna | 274 | 389 | 596 | 32.23 | 45.76 | 70.12 | 41.98 | 53.25 |
| 31 | Cart Road (N.C.) | 11440 | 11038 | - | 6.35 | 6.14 | NA | -3.31 | NA |
| 32 | Mahanadi Forest | - | - | - | - | - | - | - | - |

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