GEOMORPHOLOGY OF TRIPURA

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INTRODUCTION

Geomorphology is the science of landscapes. It describes the landforms and attempts to explain their origin in terms of geology, climate and earth's surface processes.

Traditionally, the study was essentially concerned with interpretation of the origin and evolution of landforms in a qualitative way. The Davisian school of thought aimed at explaining landscapes in terms of the concept of cycle of erosion in relation to "Structure, Process and Stages" (Davis, 1904).[1]

In recent years, increasing attention has been paid to quantitative aspects. Morphometric techniques have been evolved for utilizing various cartographic information about the earth's surface configuration to arrive at numerical indices. Both quantitative and qualitative information provided in published topographical maps, aerial photographs and landsat imagery, or data directly collected by field investigation are utilised for this purpose. Thus geomorphology has

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[1] W.M. Davis, The Explanatory Description of Landforms, Vol. 3, Belgrade (1924), p.24.

become more rigorous.

"Geomorphology, which is concerned with landforms, materials and their related processes, is pertinent to all aspects of environmental management (Cooke and Doornkamp, 1974).[2] The scope of the subject as a science is, therefore, much wider than that of physiography which is mainly descriptive.

Earth's surface is covered with flora and fauna adapted to different climatic and terrain conditions. In addition to the physical factors, the biota imparts a specific character to the evolving landscapes. As a consequence of interaction of multiple variables, heterogeneity on micro level is an inescapable characteristic of any broad geomorphic region. But inspite of diversity, a thread of unity runs through the landscape of a specific region giving a characteristic regional signature.

STATEMENT OF THE PROBLEM

So far, no empirical study has been done in respect to the Geomorphology either for the State of Tripura or for any river basin or any part thereof. Even physiographic regional analysis of the North Eastern

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[2] R.U. Cooke and J.C. Doornkamp, Geomorphology in Environment Management, Oxford (1974), p.7.

Region of India has not been undertaken, while a number of studies on regional geomorphology of different parts of India have been done by geographers as well as geologists during the last few decades.

The State of Tripura has not yet been fully mapped by the Geological Survey of India. Geological mapping has been done by GSI only in some parts of the west Tripura District and Khowai Sub-division of North Tripura District. Landsat imageries are helping in better mapping of geological and neo-tectonic features of the State and its adjoining areas. Socio-economic and statistical bulletins, published by the State Government give very little physiographical and geomorphological information. Considerable time has been devoted in the collection and compilation of rainfall, humidity and temperature data for a period of 29 years (1950-1978).

At the initial stage of research work, the researcher had to visit Agartala, the Capital of the State for several times. Field investigation was tedius and difficult mainly due to poor communication system difficult terrain in the eastern part of Tripura, and hostile activities of the insurgents in the hilly terrain of the region. Due to paucity of sufficient published

geological, geomorphological and meteorological data base, this research work is mainly based on field investigation, conducted by the author in different field seasons.

OBJECTIVES

In the present study an attempt has been made to investigate and interpret the geomorphic elements, processes, and forms and their spatial distribution. One of the objectives is to find out the main characteristics of the geomorphic elements and their resultant effect on the regional geomorphological processes which had operated in the past geological periods and continuing even today also. The State of Tripura forms a geomorphic region with alternate north-south trending hill ranges and river valleys. One can easily demarcate its boundary with deltaic Bangladesh.

In an agricultural state like Tripura for scientific developments of agriculture terrain evaluation assumes special significance. As such, evaluation of the impact of the geomorphic processes in shaping the different landforms both in space and time, and interpretation of their characteristic manifestations form the core of this research. An attempt has been made in

the same direction, from both academic and applied points of view.

The main objectives of the study are categorically stated below:

(i) The basic objective is to investigate, examine and interpret geomorphic characteristics of the State of Tripura in relation to lithology and structural characteristics of rocks and the geomorphic processes working in the region in shaping and developing the different landforms.

(ii) To investigate the evolution of drainage systems, patterns and their characteristic features.

(iii) To investigate, describe and interpret the erosional activity, mainly under the impact of weathering processes and fluvial action of streams and rivers.

(iv) To examine the nature of differences both in structure, processes and stages in the western and in the eastern part of the Bara Mura Hill range.

(v) To examine the nature of slopes, slope elements, slope profiles and evolution of slopes in relation to rock structure, geomorphic elements and processes.

(vi) To identify the erosion surfaces with the help of morphometric tools and techniques.

(vii) To regionalise the study area in respect of both physiographic and geomorphic facies as noticed in various parts of the State.

JUSTIFICATION

The State of Tripura within its small geo-political territory represents varied topography, lithology,

lineaments and neo-tectonics, complex geological formations with numerous geomorphic elements which provide ample scope for intensive study, investigation and analysis in terms of fluvial geomorphic processes and their resultant impact in shaping the landform developments.

Tripura is one of the remote States of the North Eastern Region of India, where no systematic geomorphological study has so far been undertaken.

Some of the geographers have termed the State as a part of Surma Valley, where as the Gumti river basin is in no way a part of the Surma valley. The west flowing Gumti with its own distinct characteristics constitute a separate basin, which is directly connected to the Meghna river and occupies about one-fourth area of Tripura.

Applied geomorphology mainly deals with the problems of practical planning for the optimum utilization of the land and water resources of a region. The State of Tripura which has complex geomorphic features, the utility of the subject is immense, specially in the field of perspective agro-economic planning. The application and utility of detailed geomorphological maps are

often required. The geomorphological maps may be used as base maps for preparation and compilation of other maps, to have information about landforms suitable or unsuitable for the purpose aimed at. Specially for the purpose of land use planning, plantation, forest development, transportation, settlement to check soil erosion, construction of roads selection of dam sites, various projects for agro-economic and socio-economic developments, such geomorphological studies become more essential.

Thus, there is a need to investigate, study and analyse the geomorphic elements, specially the processes which are actively operating in the region. Morphometric analysis is essentially needed to reveal the geomorphic elements and the processes involved in the evolution of different components of the landscapes of the region as a whole.

This research is an attempt to consider the fluvial system and its components in such a way that the inherent instability of the system can be comprehended, and suitable data provided to the geologists, geomorphologists, stratigraphers, sedimentologists, landmanagers, conservationists and civil engineers. Thus, the study is important not only from the point of view of academic

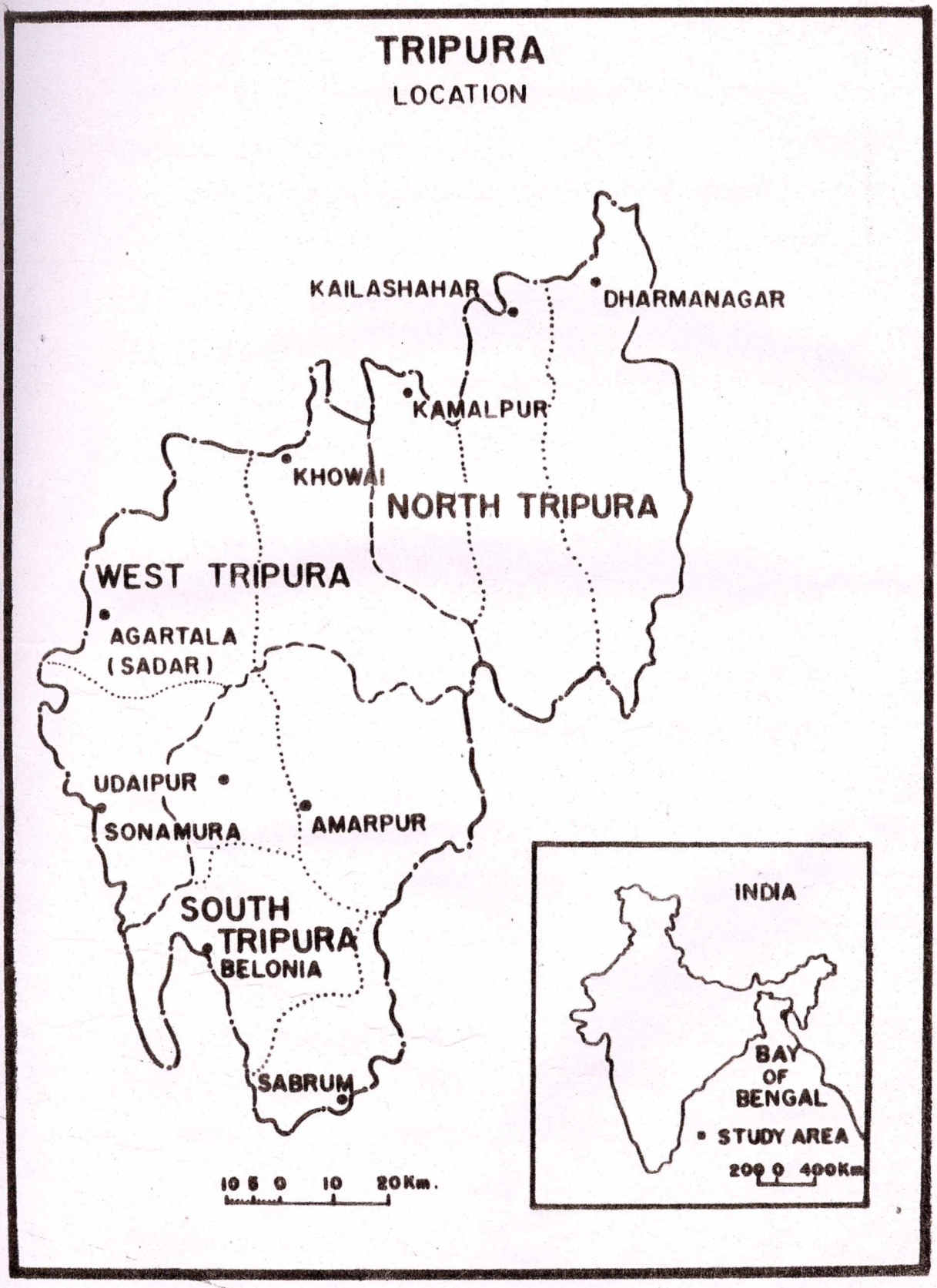
TRIPURA
LOCATION
KAILASHAHAR
DHARMANAGAR
KAMALPUR
KHOWAI
NORTH TRIPURA
WEST TRIPURA
AGARTALA
(SADAR)
UDAIPUR
SONAMURA
AMARPUR
SOUTH
TRIPURA
BELONIA
SABRUM
10 5 0 10 20Km.
INDIA
BAY
OF
BENGAL
STUDY AREA
200 0 400Km

FIG. 1

interest, but it has also practical utility.

STUDY AREA

Tripura is one of the States of the North Eastern Region of India. Geographically, this State is located in the South-Western part of aforesaid region and is surrounded by Bangladesh in the north, south and west, in the East by Cachar District of Assam and Aizawl district of Mizoram. This study area is located in between $20^{\circ}56'$ - $24^{\circ}32'$ N latitudes and $91^{\circ}09'$ - $92^{\circ}20'$ E longitudes. It occupies a geographical territory of about 10,477 sq. Kms., with maximum extent of about 183.5 Km. in East-West and about 112.7 Km. in the North-South direction. The State supports a total population of 20,47,351.[3] It is very near to the Bay of Bengal and is under the direct impact of monsoon. Tropic of Cancer passes through the southern part of the State.

Administratively, there are 3 Districts and 10 Sub-divisions as indicated in the location map. Administrative boundaries of the districts and even that of most of the Sub-divisions are delimited by the geomorphic features viz: (i) hill ranges (Muras), (ii) hills (Tillas),

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[3]Provisional Census Report of 1981, Series (21), Tripura, p.25.

(iii) rivers (Nadis or Gang) and (iv) streams (charras).

SOURCES AND DATA BASE

The materials necessary for the study as far as possible have been collected from the publications of memoirs, records and reports of Geological Survey of India; National Atlas Organisation, National Remote Sensing Agency, topographic sheets as available on various scales published by the Survey of India, Land Sat imageries, latest publications of geomorphological literature, Journals, meteorological data as published by the Meteorology Department.

Geomorphological data have been collected through extensive field studies in various parts of the study region. Recent studies and reports of the Directorate of Quaternery Geology and Geomorphology, Geological Survey of India, Shillong have yielded useful data. Many parts of the eastern Tripura have not been mapped by the Geological Survey of India. Some shallow ridges are located in the northern and southern parts, outside the study region for which data base could not be extended fully. Adjoining regions have been studied only by the landsat imageries. Meteorological data as available from the observatories located mostly in the sub-divisional

headquarters are not giving the actual rainfall that is taking place in the hilly region. Some of the observatories are installed after 1960, as such data for a very long period is not available.

Instrumental observations viz. theodolite traverse were made in some parts of dissected hills of west Tripura to prepare the slope profiles, to see the nature of slopes. Pictorial views are given at the end of some of the chapters as a supplementary evidence. Maps, figures, graphs and photographs given in the thesis attempts to give a clear picture of the natural configuration of the region, illustrating different aspects of geomorphic elements and giving birds-eye-view of the study area. All the maps and figures have been prepared by the author. To illustrate exact landform types, numerous field photographs have been given.

METHODOLOGY

Geomorphic research methodology depends mainly on the location of the study area, its litho-stratigraphic formations and the processes involved in shaping the landforms. The State of Tripura is located in the humid tropical climatic zone with heavy rainfall under the impact of South-west Monsoon. Physically and

chemically weathered materials are being transported from the hills and uplands to the lower reaches of the river valleys, under the action of streams and rivers. The nature of landform developments could be most readily and directly observed when the process is very intense viz. mass-wasting, landslides, a dust storm and hail storm or a flash flood due to cloud burst etc.

The State of Tripura is located near the Bay of Bengal, and experiences tropical humid climatic conditions. Its young topographic features are being actively shaped by fluvial processes. Available morphometric techniques, methods and tools have been utilised to analyse the linear, areal, quantitative and qualitative aspects of the subject.

If we know or establish the process which had formed the soil and litho-stratigraphic units, we can also more readily appreciate the nature of the surface features associated with them. During rainy season, debris insitu and weathered materials are being transported to the lowlying alluvial plains surrounding the hill ranges. For clear understanding of the major changes of landforms and processes involved in such changes, the knowledge of minor landform facies and

nature of their changes is a must to have an integrated picture.

Geomorphometric methods, tools and techniques of the late 19th century have become the basis of the present day approach with some modifications. Though both exogenic or endogenic forces were responsible for the initial development of Tripura and its adjoining region, yet later modifications were done by the exogenic forces. Changes of land forms are taking place under the fluvial processes which forms the main part of this study.

Generally relevant methods, principles, formulae and general aspects of the chapter concerned are given at the beginning of all the chapters. Chapter on quantitative analysis of 12 small selected basins forms the basis for derivation of some of the conclusions, out of the established correlation of the morphometric variables. While last chapter gives the conclusions and statements of the subject as a whole.

As climate changes, so do the fluvial processes by which material is relocated. Thus, division, subdivision and grouping of the land surface is quite

different from the classification of surface features which is precisely concerned with their spatial associations. For the purpose of spatial analysis of important geomorphic elements, features, processes and for proper regionalisation, landsat imageries have been consulted.

Figures and tables are given chapterwise; maps, graphs, profiles and statistical tables constitute the main part of the chapter along with relevant descriptive and analytical literature. Again each chapter has been sub-divided into several parts according to the contents of the chapter concerned.

PLAN OF WORK

In the introductory chapter, general aspects statement of the problem, objectives, justification of research, study area and its location, data base and its sources, methodology and plan of work have been focussed.

In the second chapter, an attempt has been made to discuss the geology. In fact geology plays an important role in shaping the geomorphic features of Tripura. It is also attempted to investigate why within a small region geological formations are different

at various areas, specially the geological contrast between west Tripura and east Tripura is explored to explain the variations in geomorphological expressions.

In the third chapter, the development of landscapes under the impact of internal and external processes is highlighted. The present day topography is the outcome of interaction of tectonic and fluvial processes. The nature of important geomorphic features of the State viz. river valleys, streams, flats, slopes, remnant hills and hill ranges is examined in detail. The distribution pattern of these elements is analysed and explained. For better understanding of the fluvial geomorphic processes, the following aspects have been considered :

(i) a study of watershed zones;

(ii) an assessment of climatic factors;

(iii) an examination of the geomorphic elements;

(iv) an assessment of the nature of fluvial erosion, and

(v) a study of the denudation history and evolutionary course of drainage development etc.

In the fourth chapter quantitative analysis of 12 small selected basins have been presented to reveal both linear and areal aspects, particularly of the basins

and generally of the region as a whole. The method of R.E. Horton (1945)[4] as modified by A.N. Strahler (1952)[5] has been applied for quantitative analysis of drainage network.

Numbering, ordering, measurement of stream lengths are done for computation of the sinuosity indices of all the selected basins. Stream frequency, drainage density and average slope have been worked out for mapping etc. In this chapter it is also attempted to correlate twenty two morphometric variables with the help of computer (Spectrum/7), to analyse, their qualitative inter-relationships.

In the fifth chapter, the slope form, nature of profiles, linearity and areal extent of slopes and their characteristic properties have been documented and analysed. In Tripura due to varied topography, lithology and structures, the landforms have very rare similar slopes; as a matter of fact, no particular law can be applied with certainity.

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[4] R.E. Horton, Erosional Development of Streams and their Drainage Basins : Hydrological Approach to Quantitative Morphology, Bull. Geol. Soc. Amer; Vol. 56 (1945), pp.275-370.

[5] A.N. Strahler, Dynamic Basins of Geomorphology, Bull., Geol. Soc. Amer, Vol. 63 (1952), pp.923-938.

The concept of horizonation is central to all field studies of the physical sciences and landforms may be categorised by the degree of development of its vertical cross-section. In this chapter it has also been tried to study and interpret the imprints that had been left by the tectonic and fluvial processes, both on the development of slopes. An attempt has also been made to analyse the scientific and mathematical data to explain the origin and evolution of slopes.

Chapter six deals with morphometric analysis of landforms with the aid of various morphometric tools and techniques to have a clear documentation of the geomorphic characteristics of the region.

In the seventh chapter, an attempt has been made to delimit the study area into micro geomorphic regions, to get the spatial distribution pattern of both physical and morphological units. Linear and areal extent of slopes, stream frequency, drainage pattern, relief, altitude and climatic aspects have been considered in combination with geology, rock structure, lineaments and tectonics for the purpose of regionalisation. To characterise the different morphological units, qualitative and quantitative analysis have been done in

combination with the geological literature and the conclusions have been verified in the field.

In the last chapter, Summary and Conclusions of the study have been presented, vis-a-vis the objectives.

SUMMARY AND CONCLUSION

The State of Tripura forms a part of the Indo-Burman orogenic belt. It was initially raised from the sea bed towards the end of the tertiary period. The Quatenary record indicates undulated continental environment. The elevation of the study area at present ranges from 15 metre in the west to 1000 metre in the east, while the average elevation varies from about 50 metre to 650 metre above the sea level. Each successive hill ranges and the intervening river valleys are progressively higher to the east. Older geological formations are also exposed in the same order. Again the hill ranges are generally higher in the central part due to a transverse cross-fold extending from the Mizo Hills to west-Tripura. The hill ranges of Tripura fade under the plains of Bangladesh in the north, west and south.

The stratigraphic record of Tripura is sub-divided into five main geological sub-groups as follows:

(i) Recent Alluvium (ii) Older Alluvium (Dupi Tila)	Quaternary
(iii) Tipam (iv) Boka Bil, and (v) Bhuban	Neogene

The north-south trending structural hill ranges are mainly formed by Boka Bil and Bhuban formations, the synclinal valleys in between the anticlinal hill ranges are filled up by the Tipam Formation and younger formations.

Western part of the Bara Mura hill range along with some other isolated patches in the northern and southern parts of the river valleys are underlain by alluvial formations of both Holocene and Pleistocene period. Alluvial plains surrounding the lower reaches of the major rivers are of Holocene age, whereas, the lowlying bad lands fringing the valley flats are of Pleistocene age. Sedimentation during the Cainozoic era was a discontinuous process, punctuated by breaks due to tectonic events.

The intensity of fold movement is higher in the eastern part. The domal shaped folds of the western part belong to later generation of earth movements.

The Bhuban Formation consists of grey siltstone,

well-bedded hard grey sandstone and siltstone of Miocene age. It forms the core of the resistant anticlinal hill ranges.

The Boka Bil Formation is conformable with, and gradational to both the underlying Bhubans and the overlying Tipams. This formation consists of shales, claystones and mudstones, and is of Mio-Pliocene.

The Tipam Formation comprises medium yellow to light buff and brownish yellow sand rock. This is mainly a sand body with minor shale and siltstone interlayers.

The Older Alluvium Formation (Dupi Tila) is of Pleistocene age. It consists of mottled clay, sand and silt of fluviatile origin. Ferruginous nodules in it are pedogenic.

The youngest geological formation of the State is Recent Alluvium. It consists of unconsolidated silt, sand, clay and peat layers and occurs in all the flood plains in the inter-montane river valleys.

The important tectonic and geomorphic features in the region are :

(i) Lineaments,
(ii) Trend lines,
(iii) Regional fold structures,
(iv) Ridge forming resistant litho-stratigraphic units,
(v) Hill ranges and river valleys.

The lineaments and other tectonic elements record the imprints of crustal forces which have deformed the sedimentary pile in successive phases.

Few long lineaments and trend lines are mostly in the NE-SW direction at about 45° angle with the synclinal and anticlinal axes. The important sets of lineaments in the region are NE-SW, WSW-ENE and NW-SE of which NE-SW trending lineaments are very prominent. A transverse cross-fold forms the watershed of important north and south flowing rivers.

The State constitutes one broad physiographic region with alternate north-south aligned hill ranges and river valleys.

Important hill ranges from west to east are:-

(i) Bara Mura
(ii) Athara Mura
(iii) Longtarai,
(iv) Sakhan, and
(v) Jampui

Important rivers of the State are :-

(i) Gumti
(ii) Khowai
(iii) Manu
(iv) Deo
(v) Dholai
(vi) Haora
(vii) Buri Gang, and
(viii) Juri

Most of the forests are located in the hills of east Tripura. There are some bills (shallow water-body) in the west Tripura, four important bills are located in the Khowai river basin which are namely :

(i) Malakachi Bill
(ii) Champlal Bill
(iii) Sarlu Bill, and
(iv) Brahma Bill.

Most of the springs of the region are warm springs. The water temperature slightly exceeds that of normal ground water temperature, Garam Charra near the Athara Mura is a good example.

Structural hill ranges of sedimentary rocks have been cut across by three important rivers, viz.,

(i) the Gumti, (ii) the Khowai and (iii) the Deo. The west flowing Gumti river has crossed three important hill ranges viz., the Athara Mura, the Bara Mura and the Sona Mura and is an antecedent river. The Khowai also has some antecedent characteristics.

Under the impact of south-west monsoon, Tripura receives an average annual rainfall of about 234.67 cms. The amount of annual rainfall increases from SW to NE, highest being in the easternmost Dharmanagar Sub-division i.e. 267.05 cm.

The temperature is moderate, the mean for the year is about 25°C. Average temperature in the summer months of May-June is 35°C and minimum average is about 10°C in the winter months of December-January.

There is a great variation in relative humidity from season to season, but throughout the year remains above 60 per cent. Due to the high rainfall, moderate to high temperature and vegetation cover etc., humidity is generally very high.

The minor streams flow mostly at right angles to the direction of main streams. Drainage density and

frequency of streams in the region depends mainly upon the following factors :

(i) Climate,
(ii) Lithological and structural characteristics of rocks,
(iii) Relief,
(iv) Infiltration capacity,
(v) Vegetation, and
(vi) Stage of development.

During the monsoon period frequent cyclones, hailstorms and flash floods cause damage to crops, vegetation and settlement with their maximum impact on erosional processes.

The existing landuse pattern like jhuming and agriculture on hill slopes are accelerating soil erosion.

Headward erosion is very prominent and active in the Pleistocene formations, and the gullies are actively heading towards the ridges formed by the Tipam and Surma formations having moderately steep (10° - 15°) slopes. Here the streams are of higher order with comparatively higher hydraulic energy.

Fluvial erosion implies consecutively the disintegration and fragmentation of rocks and setting in

motion of the weathered materials through the streams into the channels to the base levels (Grand Base Level of the Bay of Bengal or local), operations which result in the form of the valleys, the slopes and the hill crests. Physical and chemical weathering is predominant in the region.

Numerous meanders are developing in the lower reaches of the north flowing rivers, whereas there are dry abandoned meanders and ox-bow lakes in the lower reaches of the Gumti river. The western part of Bara Mura i.e. Gumti river basin is most probably in mature stage, the eastern part of Longtarai is in young stage and in between the landscape is proceeding from young to early mature stage.

The rivers of the region are neither broad nor deep enough for navigation, though some of them are wider. All the rivers traverse through Bangladesh before they fall into the Bay of Bengal.

Present day sedimentation is taking place in the lower reaches of the important rivers where channel bars and extensive flood plains are developing. The sediments comprise sands, silts and clays. Development

of flood plains is taking place in the river valleys where the valley bottom is 'U' shaped. In the upper reaches of almost all the rivers both headward erosion and valley deepening is active. It is observed that slope, lithology, pedology, vegetation cover and mean annual run-off determine the rate of active erosion.

The processes of weathering, mass wasting, sheet wash and landslides are significant in the eastern parts. Fluvial deposition is responsible for the development of alluvial plains in the low lying lower reaches of the rivers. The package of processes are not only lowering the elevations of the ridges, but also developing and shaping the landforms on the existing topography in between the interfluves.

Erosion capacity under the fluvial action increases with the increase of the hydraulic energy of streams and rivers in the rainy season. Even dry streams swell dangerously with the rise of water level to more than 4/5 metres during rainy season, which actively discharge waters of their catchments to the major streams.

The landscape of Tripura is far from static.

It is changing fast under the combined impact of natural and human activity.

Climatic, geological and geomorphic factors of nature play the dominant role in changing the scenery.

Point bar deposition is taking place in all young and gentle rivers of the eastern parts whereas channel bar deposits are prominent in case of late young or early mature river channels of the western parts.

Due to the relative absence of hard rocks, stones and pebbles are not common; hence the rate of mechanical abrasion of the river-bed is comparatively low.

Destructive forces have crossed the threshold of resistance of the structural sedimentary high hill ranges, and as a result recent dissections are taking place mostly along the crests.

The quantitative analysis of twelve selected sample basins of the region reveal that :

(i) There is a close relationship between area of the small basins and number of stream segments.

(ii) There is a linear relationship between the stream segments and orders. Mean stream length of any basin increases with the increase in order of the basin.

(iii) Cumulative mean stream lengths of first, second and third order segments are having regular relationship.

(iv) Topographic sinuosity indices of the basins indicate that the topography of the western Tripura is well developed in comparison to the eastern parts.

(v) Bifurcation ratio of 11 basins out of the 12 selected basins vary from 3.58 to 4.50 which indicates the mountainous topography and dissected basins.

(vi) It can be postulated for the State of Tripura that bifurcation ratio is inversely related to the relief, its dissection and structure.

(vii) Most of the basins are in sinuous course (SSI = 1.00 to 1.50), with only exception to the Garam Charra where few hot springs are located (SSI = 1.06).

(viii) Impermeable sub-surface materials, sparse vegetation and rugged topography, is responsible for the high drainage density of 6 basins out of 12 small basins i.e. 3.18 to 4.50 km per Km^2.

(ix) Stream segment and stream length of respective order of all the basins are having high positive correlation i.e. 0.63 to 0.87. This relationship decreases with the increase in order of the basin.

(x) Highest range of correlation have been observed between the sinuosity indices i.e. - 0.77 to 0.94, of which correlation between channel index and valley index is

highest, between hydrological sinuosity index and topographical sinuosity index is lowest. Moderate positive correlation exists between valley index and standard sinuosity index i.e. 0.57.

(xi) Standard sinuosity index is positively correlated to all other variables except topographical sinuosity index, drainage density and stream frequency i.e. -0.40, -0.38 and -0.45 respectively.

(xii) Constant of channel maintenance ranges from 0.22 to 0.31.

In Tripura slope is the single largest determinant of landforms that affects man and physical environment. There are five slope categories within the State which are :

(i) gentle ($0-5^{o}$)
(ii) moderate ($5-10^{o}$)
(iii) moderately steep ($10-15^{o}$)
(iv) steep ($15-20^{o}$) and
(v) very steep ($> 20^{o}$)

For the purpose of micro level analysis gentle slope category have been divided into two sub-units viz., (a) very gentle ($0-2^{o}$) and (b) gentle ($2-5^{o}$). Areas with very gentle and gentle slopes are having highest population density. All towns, educational institutions, settlements and all sorts of organised human activities are confined to these areas in sharp contrast to the uplands and hills with rugged topography, steep slopes having scattered huts and small villages. Debris slopes consist of weathered clay and coarse eroded

materials which cascade down from the crests and scarp faces and rest at the lower parts. Debris slopes are dominant in the western and northern parts of Tripura. The slope of this distinct geomorphic unit varies from 10° to 15°.

The system of slopes includes free face, constant slope, waning slope and waxing slope respectively from the crest to the alluvial plains.

Parallel slope retreat is visible along the steep and very steep slopes in the high hills of eastern Tripura which is responsible for the development of narrow, steep, high hill ranges with narrow to wide smooth surface along river valleys in between the successive hill ranges.

River profiles are closely related to the rock type, structures, geomorphic processes and stages. Every resistant layer of the sandstones cropping out in the course of the important rivers, has caused rapids or waterfalls. A landscape of intense dissection with moderately steep slopes (15°-20°) has evolved as a result of sculpturing of the hills by running water.

Co-existence of steep slope and deep narrow

valleys is very much prominent in east Tripura where ridges and faults run parallel, and the topography is highly dissected. In west Tripura, the slopes are gentle, the hills are subdued and the inter-montane valleys are wide.

The linear and areal distribution pattern of the average slopes in the region reflects the salient features of the topography in relation to geological structure, rock formations, dissections, relief, lineaments and altitude.

In general, slope profiles are convexo-concave, whereas, hills represent convex and river valleys represent concave profiles.

The break-in-slopes between different levels of the undulating terrain, unconformities in between the lithological formations, presence of rapids and waterfalls define neotectonic activity and phased differential erosion and sedimentation during different geological periods.

In western Tripura, valleys dominate the landscape, whereas in the east, hills are prominent.

Lithologic differences, as reflected in the slopes, are very less in the west Tripura, whereas, it is very prominent in the eastern parts. The amplitudes and altitudes of the anticlines are higher in eastern Tripura where shapes of the valleys are primarily 'V' shaped.

There is a close association of particular slope category with particular lithology, structure and drainage pattern; and this factor may be taken as one of the parameters for scientific landuse planning.

Drainage density (Km. per sq. km) have been divided into four categories which are -

(i) Coarse (0-2)
(ii) Medium (2-4)
(iii) High (4-6)
(iv) Very high (>6)

Very few basins has only less than 10 per cent of their total area under the coarse category which indicates youthful topography is dominant. Generally high percentage of area is covered by the mediumr category.

Drainage density is inversely related to the

landslopes which may mathematically be represented as :-

$$Dd \propto \frac{1}{A_S}$$

Where D_d = drainage density, and

A_S = average slope in degree

Stream frequency (Km. per Sq. km.) have been divided into four categories which are :

(i) Coarse (0-4)
(ii) medium (4-8)
(iii) high (8-12) and
(iv) very high (>12)

In most of the basins, stream frequency per sq. km. is either medium (4-8) or high (8-12). Only streams of the low lying alluvial plains has coarse (0-4) and medium (4-8) stream frequencies, and generally frequency increases with the increase of altitude towards the east.

Alluvial plains of west Tripura have coarse stream frequency and medium drainage density. East Tripura has higher stream frequency and high drainage density. This may be attributed to the presence of trellis pattern of drainage system. Characteristically

slopes 10^{o} to 15^{o} have developed medium drainage density and medium stream frequency.

There are five drainage patterns of which radial, dendritic and trellis are prominent. The central and southern parts where radial pattern is most dominant, indicates the domal character of the recent landforms.

In general drainage patterns reflect the influence of initial slopes, inequalities in lithologic composition, structural control of folds, faults, lineaments, recent diastrophism and geomorphic history of the region.

The rectangular pattern as reflected by the main channels of the Gumti river and of the Khowai river which have cut across the structural hill ranges bears the evidence of upliftment and subsidence due to major tectonic disturbances in the geological past.

The Trellis pattern has developed in the areas of lime-stone and along Sakhan and Jampui folded ridges of resistant rocks.

The frequency of landslides and intensity of

mass wasting is very high. It appears to be increasing due to human interference.

Morphometric analysis helps in identifying various geomorphic parameters, which in turn helps in identifying various erosion surfaces. The characteristic properties provide sufficient clues to visualise and reconstruct the geomorphic history of the State.

In the State of Tripura there are two distinct erosion surfaces viz :

(i) Pre-Pleistocene (generally above 200 metre)

(ii) Pleistocene-Recent (generally below 200 metre) or Quaternary.

Quaternary surface includes all alluvial fertile land of the state, whereas Pre-Pleistocene surface occupies insignificant space along the structural resistant hill ranges and hills of the eastern Tripura.

Pre-Pleistocene being the older one includes higher and older remnant surfaces mostly in the east Tripura. The geomorphic features and their pattern of landscape modifications in the State reflect that it has witnessed a number of earth movements. Its tectonic history can be traced through the lineaments,

trend lines, folds, faults and fractures in the geological substrata.

Sharp change in relief is marked by break-in-slope on the margin of the anticlinal hills and hill ranges of east Tripura. These resistant structural hill ranges are passing through a phase of vigorous gully erosion. However, no inversion of topography has taken place yet, pointing to youthful stage of geomorphic evolution of the landscapes.

The present stage of evolution is characterised by active sculpturing of the hills, and transfer of mass from the hills and uplands to the intermontane river valleys.

Jhum cultivation on the hills and other unplanned agricultural activities on the hill slopes are mainly responsible for the deforestation and aggravating the soil erosion.

Human inter-action is bringing about rapid changes in the alluvial fertile landscape of Tripura. It is also accelerating rate of mass wasting on the hill slopes.

Physiographically, the state may be divided into three distinct categories, which are :

(i) Alluvial plains,
(ii) Uplands and Hills, and
(iii)High hill ranges.

The land form facies of the State has been classified into 5 micro-geomorphic regions viz:

(i) Recent and old flood plains,
(ii) Moderately dissected residual hills,
(iii)Highly dissected rounded crests,
(iv) North-South trending hill ranges, and
(v) Eastern most high Jampui hill range.

Differential landforms can be traced surrounding the resistant structural hill ranges i.e. from anticlinal axis to the synclinal axis, which also indicate the development of differential erosion, that had taken place during various geological periods. Major erosional and depositional landforms of the region are of the Pleistocene period.

Fertile alluvial plains should be used for multiple cropping, inspite of settlements. The settlements should be done on the less fertile round shaped small hills (tilas) of Pleistocene deposits, as these are also safe from flood destruction. For the maintenance and development of natural environment,

the uplands and hills should be utilised for plantations and forest developments, which is also a potent soil conservation measure.

Jhum cultivation on the hills and other unplanned agricultural activities on the hill slopes are mainly responsible for the deforestation, which may be replaced by cultivation under the terracing system. Bench terracing is best suited in Tripura, it is also a run-off and erosion control measure.

If the geomorphic features and elements are properly interpreted, analysed, integrated and utilised, this region with vast fertile alluvial plains, forests, ground and surface water potential and manpower can easily be developed, suitable multiple cropping system may be designed, to boost up its agricultural production.

This study shows that scientific landuse planning taking into consideration the geomorphological realities holds the key to the economic prosperity of Tripura.