CHAPTER III

MORPHOMETRIC ANALYSIS OF RELIEF AND DRAINAGE AND THEIR RELATIONSHIPS WITH SOIL EROSION

INTRODUCTION :

This chapter deals with analysis of various , morphological features and those discussed in detail are profile , drainage patterns, drainage density , drainage order , drainage frequency , number and lengths of streams , bifurcation ratio , stream length ratio , sinuosity among the drainage characteristics and cross and composite profiles . Ruggedness , slope zones , relative relief , hypsometric analysis related to the slope and relief characteristics are also discussed here .

3.1 DRAINAGE LONG PROFILE :

The long profiles of all the five rivers in the study area have been calculated and tabulated in he table 3.1 . The cross profile data has also been plotted in Fig 3.1. The general slope of the rivers , with exception of Rinchintong , goes on reducing . Overall gradient of Ghatta - Hussain , Pachim ,

LONG PROFILE

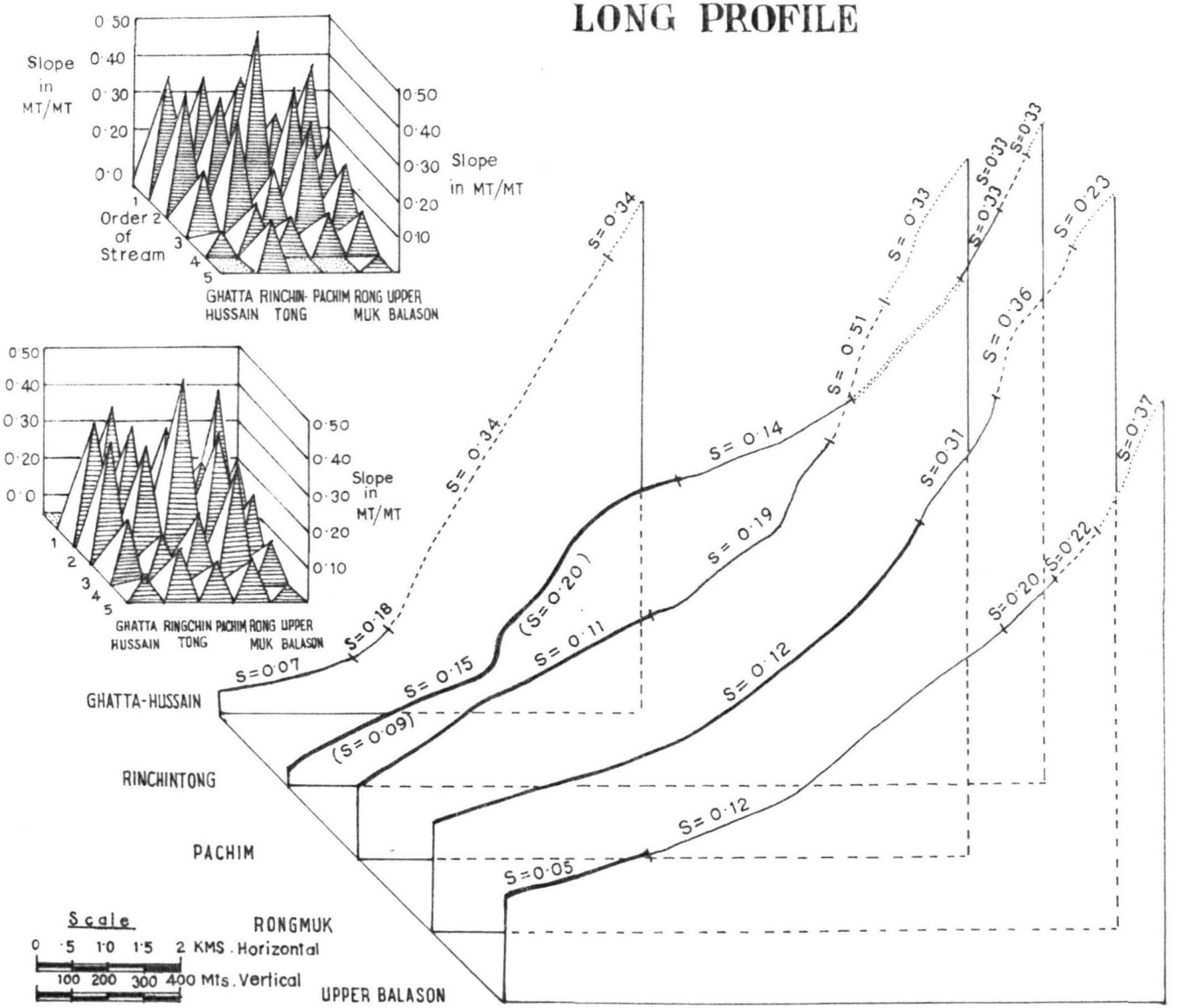


Fig. 3·1

Rongmuk and the Upper Balason rivers are , respectively , 0.22 ,0.20 , 0.18 and 0.15 mt per mt (Fig 3.1) .

The only exception is the Rinchintong river which has an over all gradient of 0.17 mt per mt whereas the ghatta - Hussain located down below adjacent to it has an overall gradient of 0.22 mt per mt and the Pachim , located higher up next to it , has 0.20 mt per mt .

TABLE 3.1

LONG PROFILE OF STREAMS

STAT	GT-HSN		RNCHNTONG		PACHIM		RONGMUK		U.BLSON	
	DIST MT	ALT MT	DIST MT	ALT MT	DIST MT	ALT MT	DIST MT	ALT MT	DIST MT	ALT MT
1	0	550	0	550	0	700	0	800	0	800
2	1200	600	950	600	750	800	1900	900	1900	900
3	2350	700	1400	700	1500	900	3200	1000	3300	1000
4	2650	800	2800	800	2500	1000	4200	1100	4300	1100
5	2850	900	2900	900	3350	1100	4850	1200	4800	1200
6	3100	1000	3400	1000	4500	1200	5500	1300	5500	1300
7	3400	1100	3750	1100	4950	1300	6000	1400	6150	1400
8	3750	1200	4050	1200	5800	1400	6450	1500	6900	1500
9	4000	1300	4950	1300	6100	1500	6750	1600	7450	1600
10	4350	1400	6500	1400	6400	1600	7150	1700	8000	1700
11	4600	1500	7500	1500	6650	1700	7600	1800	8350	1800
12	4900	1600	8100	1600	6850	1800	7800	1900	8650	1900
13	5250	1700	8600	1700	7050	1900	8000	2000	8850	2000
14	5600	1800	9150	1800	7250	2000	8150	2100	9100	2100
15	5900	1875	9500	1900	7550	2100	8600	2200	9250	2150
16			9850	2000	7800	2200	8900	2300		
17			10150	2100	8100	2300	9200	2400		
18			10400	2200	8500	2400	9600	2500		
19			10600	2300						
GRADIENT	.22%		.17%		.20%		.18%		.15%	

GT-HSN = Ghatta - Hussain basin ; RNCHNTONG = Rinchintong basin ; DIST = Distance from mouth of the river ; ALT = Altitude above msl .

(Source : Author's own calculation)

A closer look at the long profile of the Rinchintong river shows that approximately top 50 percent of the river is much more flatter than the corresponding sections of the other rivers in the study area . There is sudden rise in the level of the river after it has traversed about 25 percent of its course from its mouth . At this point the river takes a turn almost at right angle and starts rising suddenly and covers its next 25

percent of the course in this steeply rising fashion . The course of the river tapers down at about 50 percent point of its traverse which is located a little below the factory of the Dilaram tea estate . It is precisely this point where from the water of the Rinchintong river has been tapped by the Department of Electricity , Govt. of West Bengal for the Phasi Hydroelectric project . Beyond this point the flatter section of the Rinchintong river begins. Here the tea factory and the various establishments of Dilaram tea estate are located . In flatter section, the average velocity of the flow is much lower . Hydraulic radius of the river is much higher and size of the boulders in the bed much smaller .

The Table 3.2 gives the length of all the five rivers in different orders in the study area. Profiles of lognest drainage have been drawn to compare their lengths (Fig. 3.1). There are some striking features which need mention.

TABLE 3.2

LENGTH OF STREAMS

OR	LENGTH OF STREAMS IN KMS				
	GT	RN	PM	RM	UB
1	0.5	0.2	1.1	0.6	0.9
2	3.0	0.5	0.9	1.1	0.6
3	0.5	0.6	2.5	1.1	0.7
4	1.9	4.0	4.1	6.8	5.0
5	0	5.4	0	0	2.1
TO	5.9	10.6	8.5	9.6	9.3

OR = Order of streams ; GT = Ghatta - Hussain ; RN = Rinchintong ; PM = Pachim ; RM = Rongmuk ; UB = Upper Balason ; TO = Total

(Source : Author's own calculation)

One striking feature to be mentioned is the extremely long section of the river Ghatta - Hussain

falling in the second order . The entire length of the river is 5.9 km . Out of this, 3 km is represented by the second order stream . This indicates a very strong tendency to flow parallel and thus making relatively longer sections of lower order streams . The other striking feature in this regard is very long section of the river Rongmuk representing the highest order of the stream in the basin . It is seen that out of a total length of 9.6 km of the main drainage line , 6.8 km (71 percent of the entire length of the main drainage line) is of 4th order. This indicates strong tendency among the tributaries to run parallel to one another and meet the main channel directly and , probably , relatively longish shape of the drainage basin . This will definitely be reflected in the bifurcation ratio of the stream . This will also have effect on the shape of the hydrograph and peak will be less pronounced , comparatively speaking .

Table 3.3 represents the gradients of the various sections of all the five streams arranged in accordance with their orders . The data has been scribbled at the body of the individuals profiles too (Fig 3.1).

TABLE 3.3

SLOPES OF DIFFERENT ORDERS OF STREAMS

ORDER	SLOPE IN MT PER MT				
	GT	RN	PM	RM	UB
1	0.34	0.33	0.33	0.23	0.37
2	0.34	0.33	0.51	0.36	0.22
3	0.18	0.33	0.19	0.31	0.20
4	0.07	0.14	0.11	0.12	0.12
5	NE	0.15	NE	NE	0.05

(Source : Author's own calculation)

section Ghatta - Hussain has the highest overall gradient (0.22 mt per mt) . This implies that the action of the eroding agents will be most intense in this section of the river resulting in bank cutting , slides , rockfall and bebris flow . In fact , the Hussain Khola which passes almost touching the northern periphery of the Kurseong town is one of the most turbulent streams in the area . Major parts of its reaches , specially the lower reaches around the Ambootia Tea Garden , has lots of rock slides and huge scale of bank cutting.

The second interesting feature of the highest order streams is the steepest slope of the Rinchintong river (0.15 mt per mt) . It is seen that the upper half of the Rinchintong river is the flattest amongst the corresponding sections of other rivers . The Fig. 3.1 and the inset diagram , too , show the abrupt fall of the river gradient as the river descends from 4th to 5th order . The nature of the gradients of various sections of the Rinchintong river shows occurrence of harder and stiffer rocks along its course between 2500 mt and 4000 mt from its mouth . These rocks are much more resistant towards various eroding agencies than their counterparts either in the upper or in the lower reaches of the stream . The steep gradient coupled with the 5th order of the stream makes this zone most active so far as the river activities in the study area are concerned . If one takes a closer look in the corresponding parts of the other streams of the study area , one wonders why such stiff and resistant rocks are not present in the other rivers . One also wonders if these stiff rocks are only localised . If that be so ,

the possibility of the Rinchintong river changing its course in times to come can not be ruled out . The sharp right angle turn of the river at distance about 3000 mt from its mouth indicates that the river has changed its course in the past . If Rinchintong river finds more erodible rocks in its process of development , it may change its course violently affecting the flatter terrain on the upstream side and , simultaneously , bringing about very severe erosion in the area .

The third interesting feature is the uniformity with which the gradient of the river Upper Balason river decreases from the 1st to the 5th order. As is seen from Fig. 3.1 the inset diagram ,the gradient of this river is 0.31 , 0.22 , 0.12 and 0.05 mt per mt for 1st to 5th order streams in the same sequence . This shows the relative maturity of the river Upper Balason . The uniform degradation also indicates that its basin is constituted by rocks having more or less similar resistance to erosion .

The fourth interesting point about the gradients of the rivers is the highest ever gradient in the study area (0.51 mt per mt) occurring in the river Pachim in its section constituting the second order stream . This is also very well brought out by the inset diagram of Fig.3.1 . This gradient towers above all . This region is about 6500 mt from the mouth of the river and stretches for about 1000 mt . It stretches from Gorabari to Sonada bazaar. The terrain in this part , is charcterised by the steepness of the huge rock outcrops having very little or no vegetation along with huge engineering structures

constructed to support the rocks on the uphill side of the road . This part would have been the toughest to negotiate while constructing the road . This area is very prone to rock slides . In fact wherever some flattish ground is available along the Hill Cart road , one hardly ever fails to come across the human settlements . But this is not so in this stretch . The absence of human habitation in this stretch is a proof of the long standing notoriety of this region as rock fall or rock slide zone .

The fifth interesting feature is encountered in the Rongmuk river where second order stream has a gradient of 0.36 mt per mt as against 0.23 and 0.31 mt per mt for 1st and 3rd order streams respectively . This region is encountered about 1000 mt from the top of the river Rongmuk. Near Banglakhola PHE station on Hill Cart road, the stiff rock outcrops along with huge sized boulders are also discernible in the course of the stream .

An attempt has also been made to calculate the percentage long profiles of the rivers . The result has been tabulated in Tables 3.4 and 3.5 . The result has also been plotted in the Fig. 3.2 and the inset diagram in that figure .

Upper Balason and the Rongmuk show more or less same stage of degradation of their courses . The Pachim river shows that its upper reaches are as developed as those of Upper Balason and Rongmuk whereas in the lower reaches , comparatively speaking , still some degradation has to take place to reach the same stage of the development as that of Upper Balason and Rongmuk . The Rinchintong and the Ghatta - Hussain rivers are still young . It is also clear that Ghatta - Hussain river passes through

Relationship between percentage of Long profile and Relative relief.

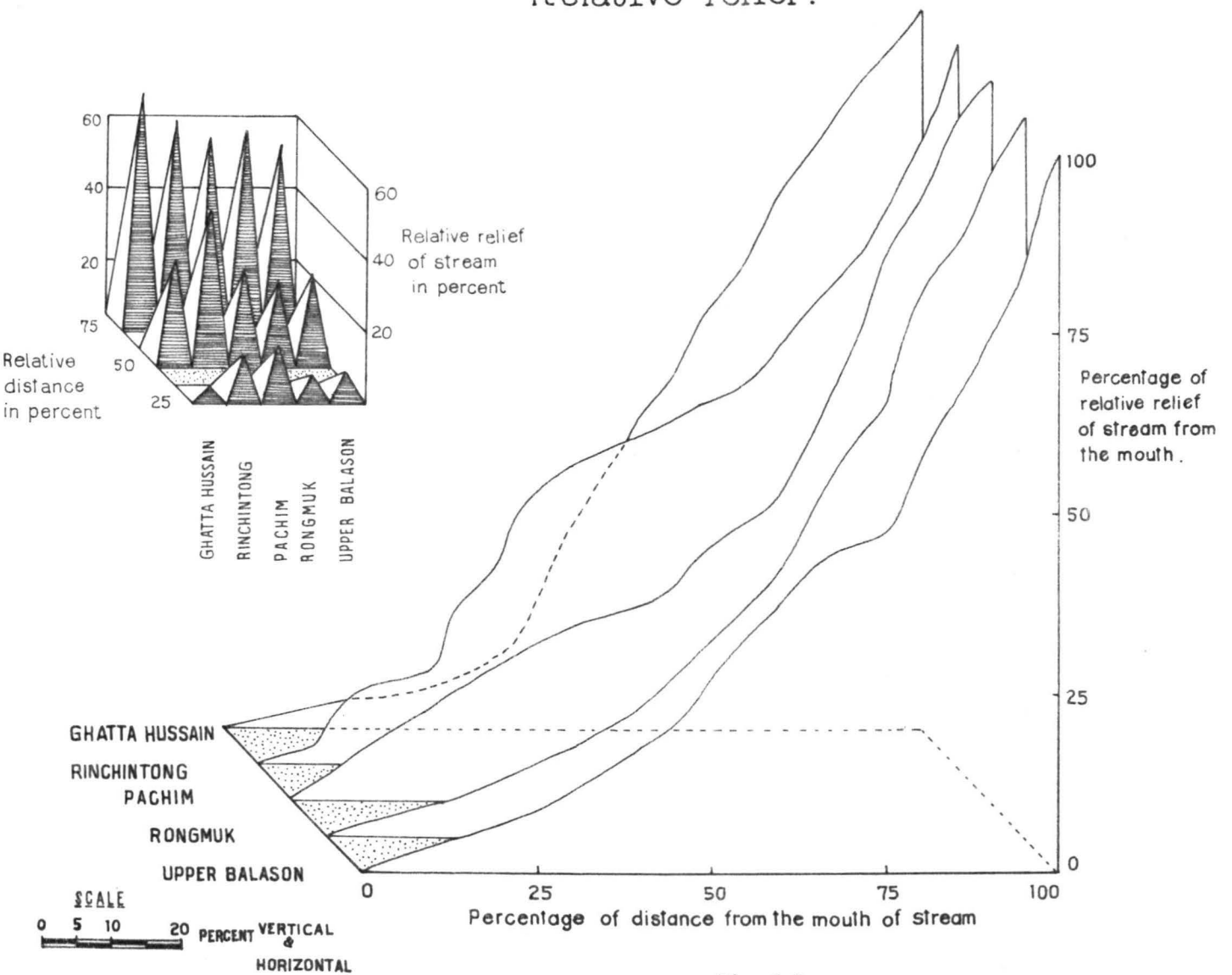


Fig. 3·2 .

rocks having uniform resistance through out its upper reaches . In case of Rinchintong river upper and lower reaches are passing through softer rocks whereas the middle reaches consist of stiffer rocks . This is also very clearly brought out by the figure (Fig. 3.2).

TABLE 3.4

RELATIVE LONG PROFILE OF STREAMS

STAT	GT-HSN		RNCHNTONG		PACHIM		RONGMUK		U.BLSON	
	DIST %	ALT %	DIST %	ALT %	DIST %	ALT %	DIST %	ALT %	DIST %	ALT %
1	0	0	0	0	0	0	0	0	0	0
2	20	4	9	3	9	6	20	6	21	7
3	40	11	13	9	18	12	33	12	36	15
4	45	19	26	14	29	18	44	18	46	22
5	48	26	27	20	39	24	51	24	52	30
6	53	34	32	26	53	29	57	59	59	37
7	58	42	35	31	58	35	63	35	66	44
8	64	49	38	37	68	41	67	41	75	52
9	68	57	47	43	72	47	70	47	81	59
10	74	64	61	49	75	53	74	53	86	67
11	78	72	71	54	78	59	79	59	90	74
12	83	79	76	60	81	65	81	65	94	81
13	89	87	81	66	83	71	83	71	96	89
14	95	94	86	71	85	76	85	76	98	96
15	100	100	90	77	89	82	90	82	100	100
16	-	-	93	83	92	88	93	88	-	-
17	-	-	96	89	95	94	96	94	-	-
18	-	-	98	94	100	100	100	100	-	-
19	-	-	100	100	-	-	-	-		

GT-HSN = Ghatta - Hussain basin ; RNCHNTONG = Rinchintong basin ; DIST = Distance from mouth of the river in percentage of total traverse ; ALT = Altitude in percentage of total fall of the river from its topmost point to mouth .

(Source : Author's own calculation)

At point of 50 percent distance from the mouth , its towering over others is noteworthy .

TABLE 3.5

COMPARATIVE RELATIVE LONG PROFILES

Distance * %	RELATIVE ALTITUDE GT %	RN %	PM %	RM %	UB %
25	5	14	16	8	9
50	30	44	28	24	26
75	66	58	53	56	52

GT = Ghatta Hussain ; RN = Rinchintong ; PM = Pachim ; RM = Rongmuk ; UB = Upper Balason ; * = distance from mouth .

(Source: Author's own calculation)

Besides the drainage long profiles , drainage density is another important characteristics discussed next .

3.2 DRAINAGE DENSITY :

The drainage density of any particular area is a function of geologic structure and climatic factors , specially , rainfall . A drainage network of specific pattern and density develops on account of the fact that streams always seek out and take advantage of weaknesses in the rock strata over which they flow . They provide useful clues about land stability , and in turn , important clues about feasibility of certain land management practices (Hornbeck , 1984) . The drainage density could be assessed for the entire basin or can also be assessed for a specified stream order where it will represent length of all channels above the specified stream order , per unit of drainage area (Langbein , 1975) . High drainage density affects run off pattern . A high drainage density moves surface water rapidly

decreasing the lag time and increasing the peak of hydrograph (Singh et al , 1991) . In other words higher the drainage density , more efficient is the drainage and more flashy is the stream flow and vice versa (Varshney , 1971) . The drainage density has an important bearing on transport of eroded material . Higher the drainage density , higher is the sediment delivery ratio (Oyebande , 1981) . The values of sediment delivery ratios varry as widely as 5 - 100 percent (Chow , 1964) .

The drainage density exhibits a wide range of values in nature and varies from 3 - 4 to as high as 1300 (Chorley , 1971) . In areas having comparable rainfall pattern it is a function of permeability of the soil mantle . The sandy soils shall show the least values and the impermeable clays the highest.

The drainage density in the study area varies from 2.0 to 6.5 km\ sq km (Fig 3.3) . The areas of highest drainage density are located between Dilaram and Gorabari (approx 3 sq km) , about one km north of Tung (approx. 1 sq km) , around Tiger Hill (approx. half sq km) , around Rogbull (approx. half sq km) and in Phulbari tea garden about 3 km south west of Gorabari . These areas shall be having flashy nature of flows, and any soil eroded shall , in likelihood , find its way down stream to the active stream . The areas which have drainage density less than 2 are located in southern most tip of the study area along the ridges . Almost entire Ambootia tea garden , a major chunk of Single tea estate and Tomsong , Dooteria , Pussimbing and Simrik tea estates are located on areas having drainage densities 2.0 to 3.5 . This shows that in these localities the soil mantle

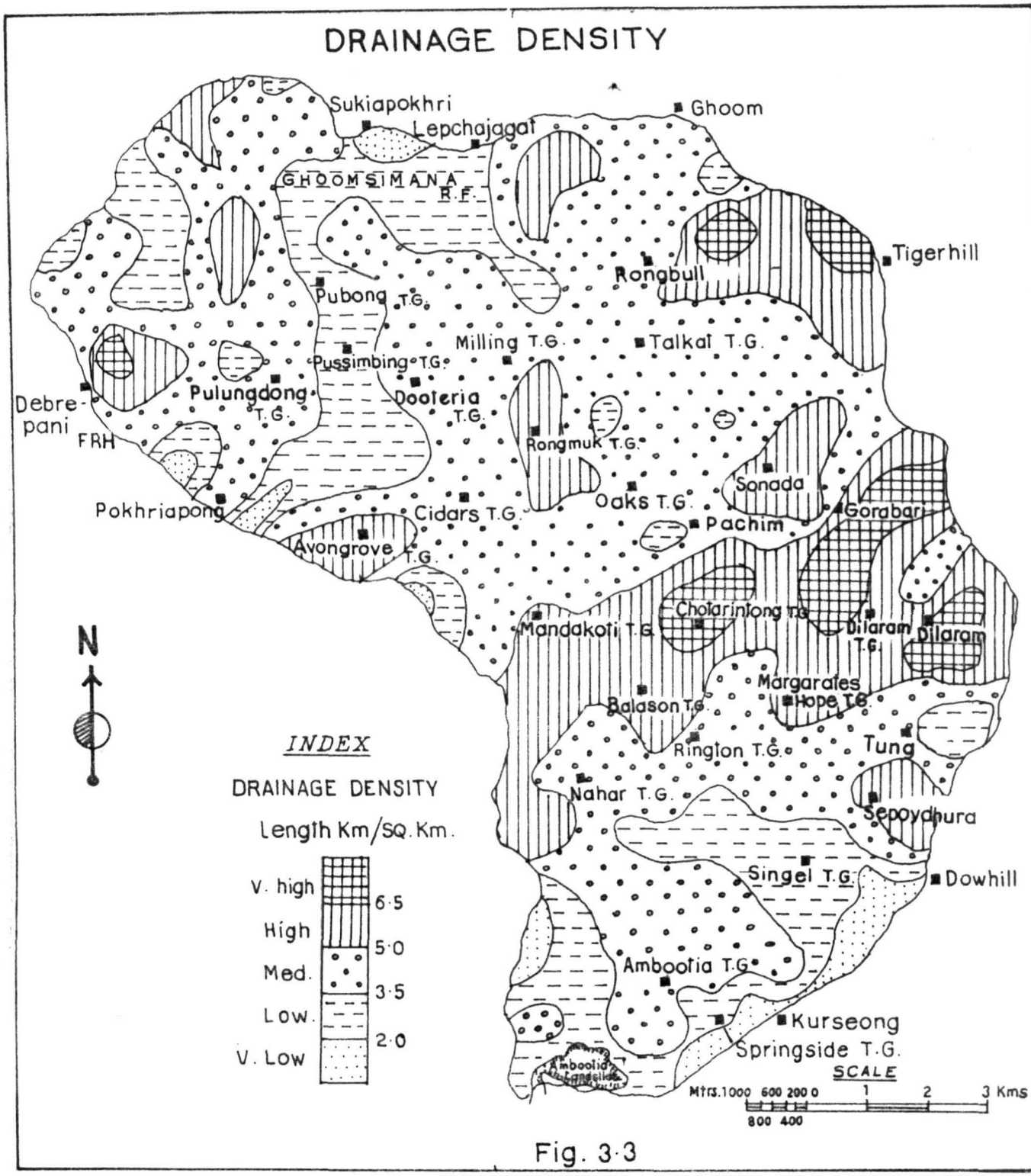

DRAINAGE DENSITY
Sukiapokhri
Lepchajagat
Ghoom
GHOOMSIMANA R.F.
Tigerhill
Rongbull
Pubong T.G.
Milling T.G.
Talkat T.G.
Pussimbing T.G.
Pulungdong T.G.
Dooteria T.G.
Debre-pani FRH
Rongmuk T.G.
Sonada
Oaks T.G.
Gorabari
Pokhriapong
Cidars T.G.
Pachim
Avongrove T.G.
Cholarintong T.G.
Mandakoti T.G.
Dilaram T.G.
Dilaram
Margarates Hope T.G.
Balason T.G.
Rington T.G.
Tung
Nahar T.G.
Sepoydhura
Singel T.G.
Dowhill
Amboolia T.G.
Kurseong
Springside T.G.
N
INDEX
DRAINAGE DENSITY
Length Km/SQ.Km.
V. high 6·5
High 5·0
Med. 3·5
Low. 2·0
V. Low
SCALE
Mtrs.1000 600 200 0 1 2 3 Kms.
800 400

Fig. 3·3

is quite permeable and , hence , probability of occurrence of landslides and rockslides shall be higher . It is seen that very high drainage density (above 5.5) is found in Upper Rinchintong , lower middle Pachim , and upper Rongmuk (Fig 3.4). Classification of zones based on weighted average shows very low drainage density (less than 3.5) in upper middle and lower middle zones of Ghatta-Hussain. Lower zones of Ghatta - Hussain and Rinchintong as well as entire Upper Balason basin have low drainage density (between 3.5 to 4.5) . The low drainage density of Upper Balason basin is quite revealing and shows that the soil mantle in this zone is quite permeable , which , combined with steep slopes in the area , makes it quite prone to landslides and rockfalls . This is probably one of the reasons of the least developed road net work here .

3.3 DRAINAGE ORDER :

Beside drainage density, the other characteristics which is of great value for understanding the drainage is the drainage order .The recognition of a hierarchy of stream segments is important because of different morphometric and hydrological features associated with each one of them . Stream ordering compares streams in within the basin (Hornbeck , 1984) . The most widely used ordering scheme (Strahler's scheme) was adopted despite some shortcomings .

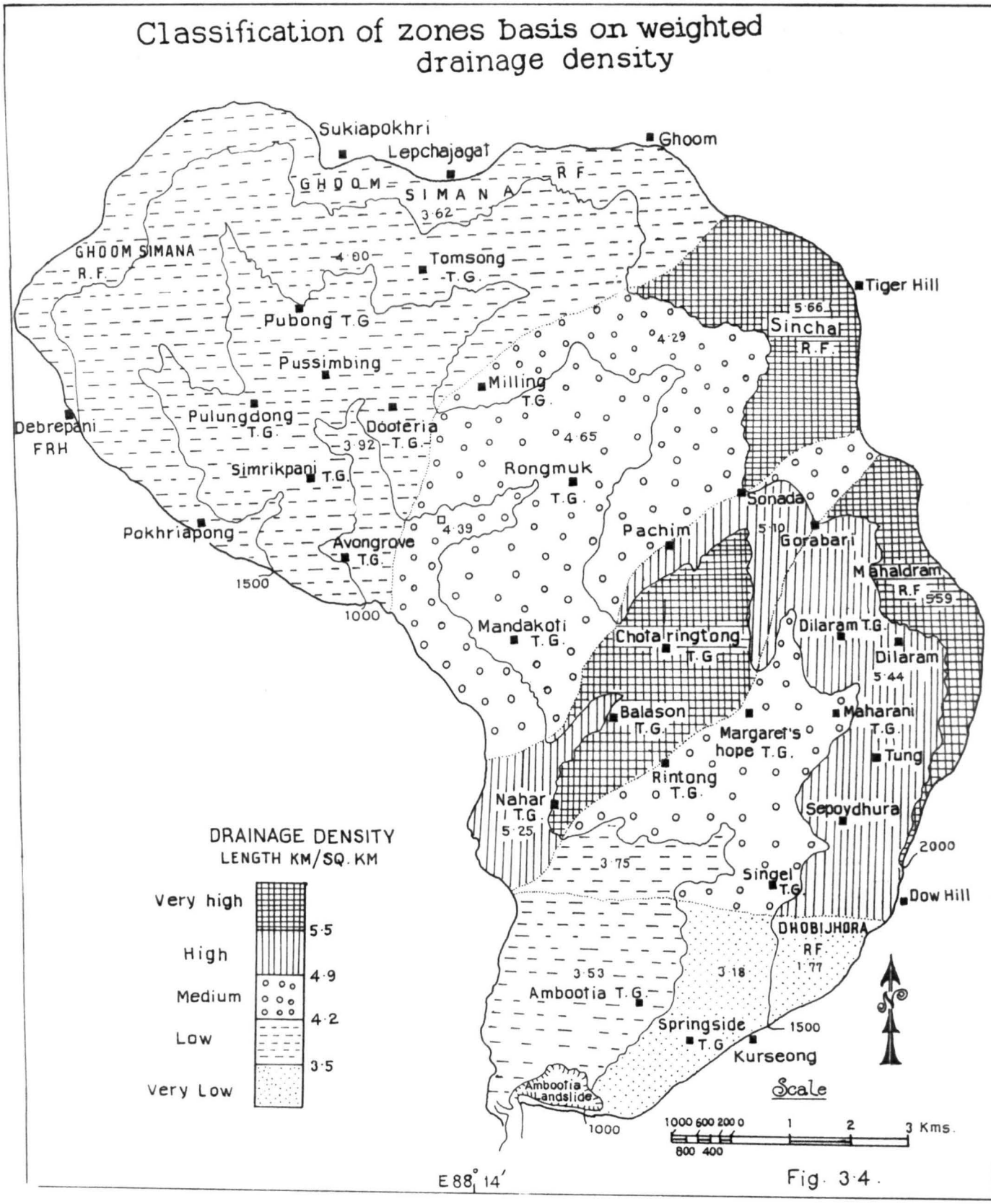

Classification of zones basis on weighted drainage density
Sukiapokhri
Lepchajagat
Ghoom
GHOOM SIMANA R F
3·62
GHOOM SIMANA R.F.
4·00
Tomsong T.G.
Tiger Hill
5·66
Sinchal R.F.
Pubong T.G.
4·29
Pussimbing
Milling T.G.
Debrepani FRH
Pulungdong T.G.
Dooteria T.G.
3·92
4·65
Simrikpani T.G.
Rongmuk T.G.
Sonada
Pokhriapong
4·39
Pachim
5·10
Gorabari
Avongrove T.G.
Mahaldram R.F.
559
1500
1000
Mandakoti T.G.
Chota ringtong T.G.
Dilaram T.G.
Dilaram
5·44
Balason T.G.
Maharani T.G.
Margaret's hope T.G.
Tung
Rintong T.G.
Nahar I T.G.
5·25
Sepoydhura
2000
3·75
Singel T.G.
Dow Hill
DHOBIJHORA R.F.
1·77
3·53
3·18
Ambootia T.G.
Springside T.G.
1500
Kurseong
Ambootia Landslide
1000
DRAINAGE DENSITY
LENGTH KM/SQ. KM
Very high
5·5
High
4·9
Medium
4·2
Low
3·5
Very Low
Scale
1000 600 200 0 1 2 3 Kms.
800 400
E 88° 14'

Fig. 3·4.

The streams in the study area have been delineated from satellite imagery dated 26th January , 1996 . It is seen that the highest order met within the area is 6 - this section lying south of the confluence point of Rincintong with Balason river (Fig 3.5) . In Upper Balason and Rinchintong and Upper Balason the highest order is 5 whereas that in Rongmuk , Pachim and Ghatta - Hussain is 4 . In case of Rinchintong the 5th order stream section stretches from near the Dilaram tea estate factory down to its mouth . The length of 5th order section of this stream is spectacular . The Rongmuk basin , despite having an area of 3675 ha (compared to 2825 ha of Rinchintong) could not produce a stream of order 5 basically on account of parallel drainage pattern on both of its banks . Both , dry and rainy season discharge of Rongmuk , prima facie , appears much higher than that of Rinchintong despite the order being lower . This is one anomaly that the Strahler system of ordering of streams brings about . It makes comparison of discharge of streams quite difficult , especially in quantitative terms , even among streams located within the same drainage unit . This is particularly so if the patterns of drainage of various streams are at variance . A parameter , combining the drainage ordering as done by the Strahler system and the drainage pattern , could probably reflect the hierarchy of streams more truly . A similar situation is seen in Ghatta - Kumale basin area where drainage lines of first and second orders show a strong tendency to run parallel to each other . Here , too , the stream order does not reflect the exact hierarchy among all the rivers in the basin .

DRAINAGE

(Based on satellite imagery , 26th January , 1996.

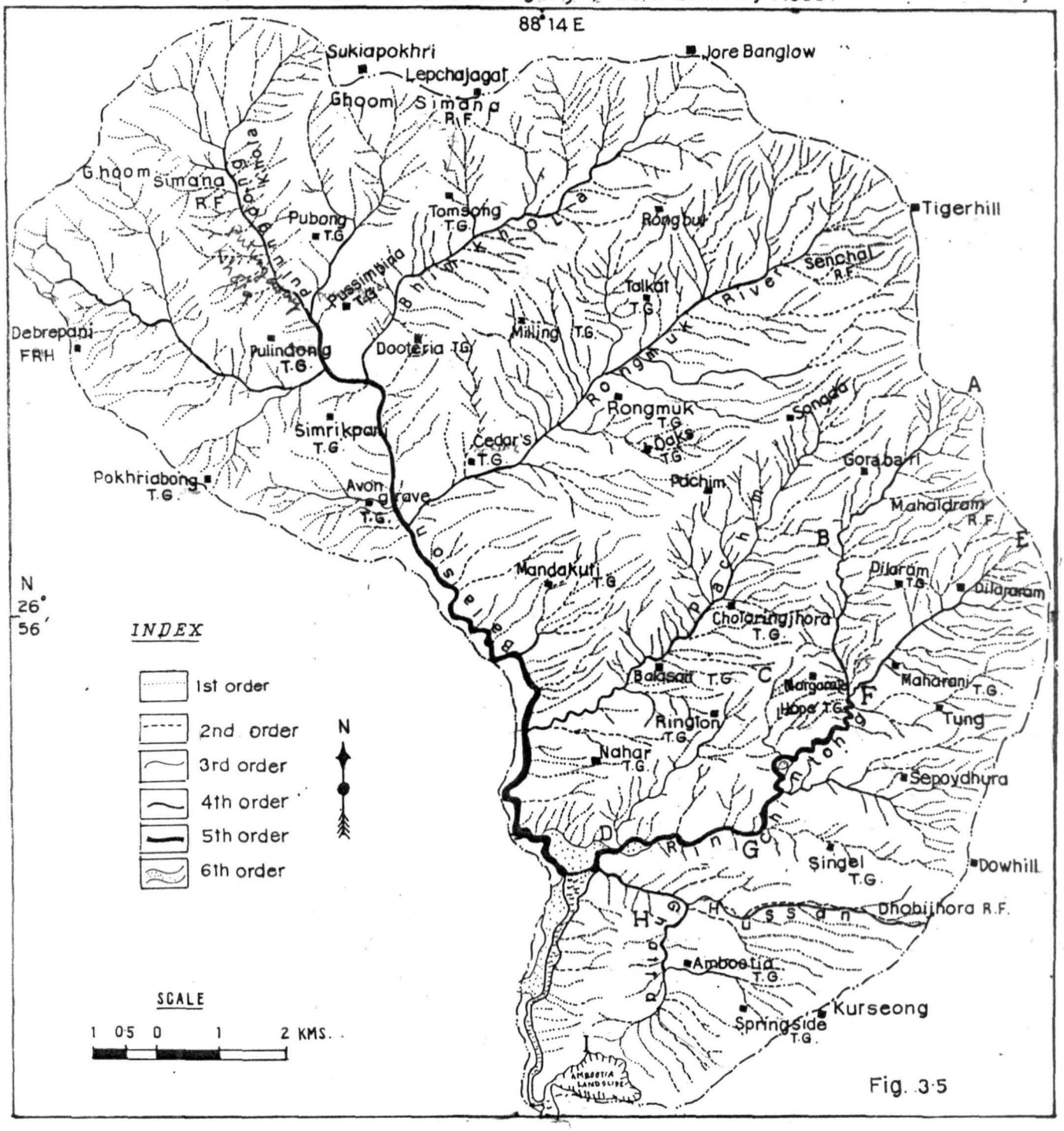


Fig. 3·5

Drainage order , by and large , gives a qualitative description of the drainage sections . The important drainage characteristics which is quantifiable to a large extent for describing a basin is the drainage frequency which is most important for determining the terrain characters .

3.4 DRAINAGE FREQUENCY :

The drainage frequency of any particular area is defined as the number of streams per unit area . The drainage frequency has been studied in the sequence of order of streams . Besides the number of streams , their lengths , too , have been subjected to analysis .

3.4.1 TOTAL NUMBER OF STREAMS :

The five river basins in the study area present some interesting features in respect of the number of streams . The number of streams of different orders in the five different basins is dependent on shape and size of the basins . Nevertheless , they provide some insight into the drainage pattern , nature of rocks , etc. of basins . The table 3.6 gives the number of streams of different order in the five river basins of the study area (Fig. 3·6).

Numbers of streams in different Basins.

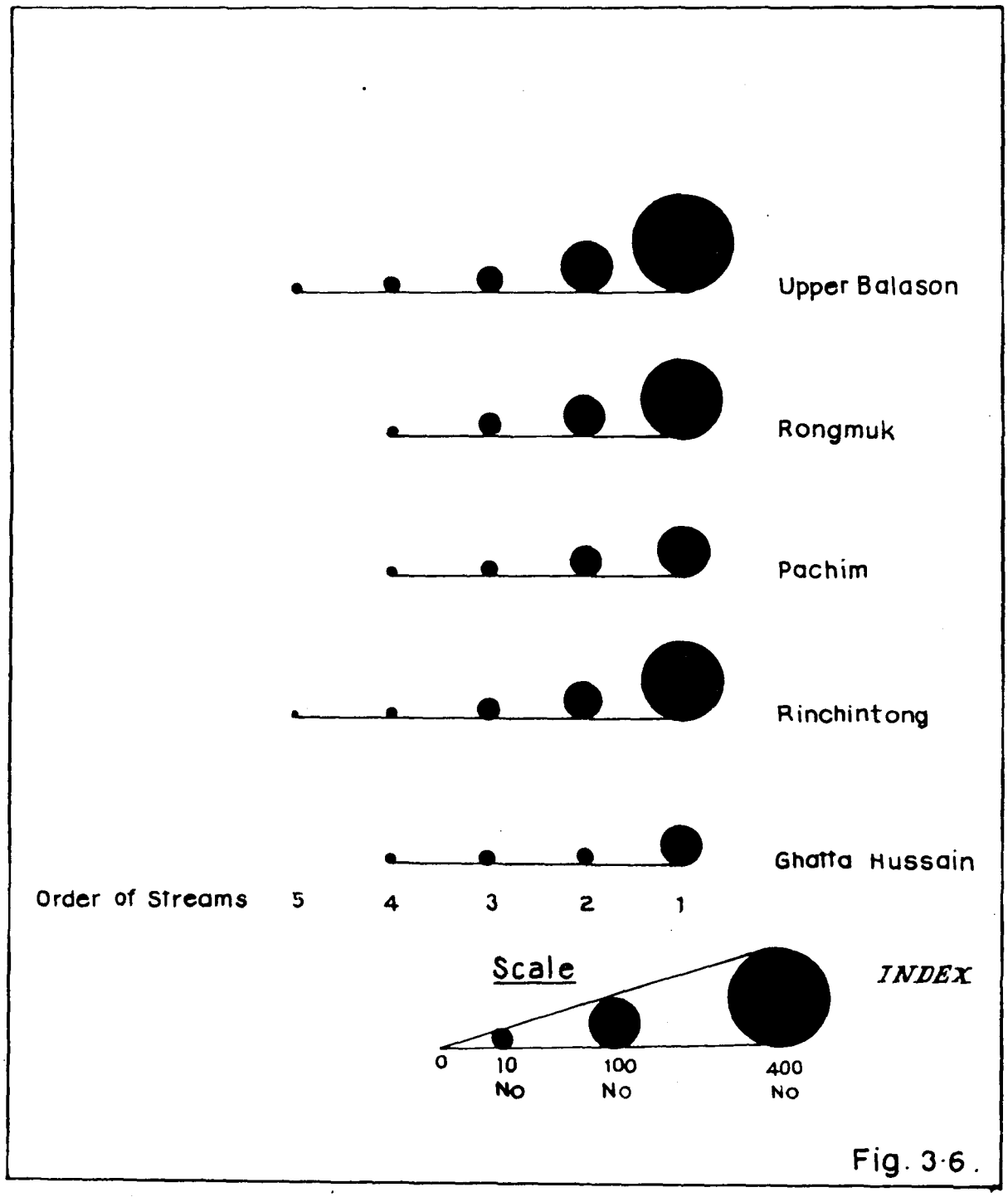


Fig. 3·6.

TABLE 3.6

NUMBER OF STREAMS IN THE BASINS

Order	Ghatta Jhora	Rinchinto-ng Jhora	Pachim Jhora	Rongmuk Jhora	U.Balason Jhora
	Number of streams				
1	59	204	101	186	330
2	10	50	28	45	71
3	3	10	6	11	15
4	1	3	1	1	4
5	0	1	0	0	1
Total	73	268	136	244	421

(Source : Author's own calculation

As is seen , the number of streams of all orders in the Ghatta jhora are spectacularly small . It can be seen that despite having an area a bit more than the Pachim Jhora , the number of streams in the Ghatta Jhora is almost as less as half . This fact very clearly shows that the area drained by the Ghatta Jhora is much more permeable than the Pachim Jhora, though the quantum and the intensity of the rain fall is the same in the two basins because of their proximity. So, sub-surface flows of the precipitation is much higher in Ghatta than that in Pachim . Again Rinchintong has an area of 28.25 sq km and that of the Rongmuk is 36.75 sq km - but the number of the first order streams in the former is about 10 percent more than in the latter . In respect of the total number of streams also , the Rongmuk Jhora is behind the Rinchintong despite having thirty percent more area . This shows that the terrain of the Rinchintong basin are much less permeable than those in the Rongmuk and , therefore , number of streams are much less in the latter .

It will again be quite revealing if one extrapolates the findings in the table 3.6 to a situation where each one of the basins is having total drainage area of 1000 ha . The reduction factor for the number of streams in the study area will be 0.58 , 0.35 , 0.63, 0.27 and 0.18 for Ghatta , Rinchintong , Pachim ,Rongmuk and Upper Balason respectively .

TABLE 3.7

NUMBER OF STREAMS PER 1000 HA IN THE BASINS (N)

Order	Ghatta	Rinchint-ong	Pachim	Rongmuk	U.Balas-on
			Number of streams		
1	34.22	71.40	63.63	50.22	59.04
2	5.80	17.50	17.64	12.15	12.78
3	1.74	3.50	3.78	2.97	2.70
4	0.58	1.05	0.63	0.27	0.72
5	0.00	0.35	0.00	0.00	0.18
Total	42.34	93.80	85.68	65.91	75.42

(Source : Author's own calculation)

Very clearly , Rinchintong and Pachim form a distinct class with very high number of streams in the basin and also in respect of the individual numbers of the streams of different orders (Table 3.7) . They are on one extreme while the Ghatta Jhora forms the other extreme . Ghatta basin has only 45 , 49 ,77, and 88 percent of the total number streams in its basin as those contained , respectively , by Rinchintong , Pachim , Rongmuk and Upper Balason basins . The Rongmuk and the Upper Balason form the category in between . This comparison of the deduced number of the streams in the five different basins shows that the rock materials are softest in the Ghatta , while they are

hardest in Rinchintong and Pachim with the Rongmuk and Upper Balason forming the intermediate category . It follows from the above discussion that while surface erosion is quite pronounced among the Rinchintong and Pachim basins , land slides , debris flows , rock slides etc. are more pronounced in the Ghatta , Rongmuk and the Upper Balason basins .

3.4.2 TOTAL LENGTH OF STREAMS :

The lengths of the streams in the study area present some very interesting features (Table 3.8) .

TABLE 3.8

LENGTH OF THE STREAMS IN KILOMETRES IN THE STUDY AREA

Order	Ghatta	Rinchintong	Pachim	Rongmuk	U.Balason
			Length in Km		
1	38	90	64	210	241
2	11	33	18	43	45
3	3	9	6	13	17
4	3	9	5	8	16
5	-	7	-	-	4
Total	55	148	93	274	323

(Source: Author's calculation)

As is seen from the table 3.8, the length of streams is the highest in Upper Balason Jhora and the lowest in the Ghatta Jhora basins . Though the length of the streams , as their numbers , is a function of the area of the basin , some clear patterns are easily discernible . The basin areas of the Ghatta Jhora (1725 ha) and that of the Pachim Jhora (1600 ha) are almost equal but the length of the streams in their respective basins shows that the basin of the later contains

almost double the total length of the stream as that contained by the former . Given the fact that both of these basins are located very close to each other , and hence the quantum and the intensity of the rainfall are almost similar. Such a wide diversity in the drainage patterns indicates towards the rock formation of these two basins . Since coarser drainage texture indicates higher permeability of the rock material , the hydraulic conductivity of the soils in the Ghatta basin is higher than that of the Pachim basin . Since surface run-off is comparatively lower , surface forms of the soil erosion such as sheet erosion , rill erosion , gully erosion are less . On the other hand , since the flow of the water is more underground , the area has a risk of having landslides and subsidence . The Pachim , on the other hand , having a higher density of the drainage lines , shows poor hydraulic conductivity of the rock material causing more surface run-off , and hence , making the basin more prone to sheet erosion , rill erosion , gully erosion, etc. Similar conclusion can be drawn about the drainage characteristics of the Rinchintong and the Rongmuk basins , even though their areas are not as comparable .

Table 3.9 has been deduced for exploring the characteristics of the basins by calculating the notional area drained by each kilometre length of the stream .

TABLE 3.9

DRAINAGE AREA OF EACH KILOMETRE OF STREAM IN HA

ORDER	GHATTA JHORA	RINCHIN-JHORA	PACHIM JHORA	RONGMUK JHORA	U.BLSON JHORA
			Area in ha		
1	45.39	31.39	25.00	17.50	22.82
2	156.82	85.61	88.89	85.47	122.22
3	575.00	313.89	266.67	282.69	323.53
4	575.00	313.89	320.00	459.38	343.75
5	0.00	403.57	0.00	0.00	1375.00

(Source : Author's own calculation)

As seen from the Table 3.9, each kilometre of the first order stream in Rongmuk is draining as low as only 17.50 ha of the basin area whereas in Ghatta Jhora drainage by each kilometre stream of that order is as high as 45 ha .Each kilometre of the first order stream in Upper Balason and Pachim drain , respectively , 22.82 and 25.00 ha of basin area whereas that figure for the Rinchintong Jhora is 31.39 . There are , therefore , four distinct categories among the five basins in the study area in this regard . The Rongmuk Jhora being very highly drained , the Pachim and the Upper Balason forming the next category i.e. highly drained , the Rinchintong being the medium drained and the Ghatta the least drained category . There can not be any simplistic explanation for such disparity in the drainage characteristics among various basins in the study area as the development of the drainage is a complex phenomenon involving multifarious factors including the dynamic geological forces . Some conclusions , however , are unmistakable .

In case of Rongmuk the length of the slope , i.e. the distance that a water drop running on the surface has to traverse to reach the stream , shall be the lowest and that for the Ghatta Jhora shall be the highest . In the former , though the

length of the slope shall restrict the soil erosion in comparison to the latter , whatever little soil is eroded on account of sheet or rill erosion shall be very likely carried down to the active stream whereas in the latter the eroded soil particles shall have much greater chance to get deposited somewhere on the way . The overall surficial erosion , shall be more severe in Rongmuk basin than in the Ghatta Jhora basin . The other basins will form the erosion hazard categories in between these two .

Another feature of the basins becomes apparent if one takes a look at the number of hectares that each kilometre of the second order streams is draining . Rinchintong , Pachim and Rongmuk present the figures of 85.61 ha , 88.89 ha and 85.47 ha respectively . Their equality in drainage in respect of second order streams , despite their wide disparity in respect of first order drainage , (31.39 ha , 25.00 ha and 17.50 ha respectively) , is quite striking . Assuming that the rainfall is fairly equal in all these three basins because of their proximity , why is it that nature provided varying kilometrages of drainage lines of first order and almost equal kilometrages of that of second order to drain the same area in these three basins ? The answer probably lies in the extent of fractures and faults in the rock material in these three basins as because the drainage lines of basins develop basically on the basis of faults of the rock materials in the basin and their order is decided by the quantum of surface flow needed to be carried to the stream of higher order . Thus the rock material is most severely faulted and fractured in the Rongmuk basin and the least in the Rinchintong basin . Heavily crushed

rocks of the Rongmuk basin can also be assessed from the parallel pattern of drainage in the basin , specially in and around Milling Tea Estate .

If one compares the drainage by each kilometre of second order of streams of Ghatta and Upper Balason basin (156.82 ha and 122.22 ha respectively) , one is simply amazed at the close similarity between these two and the wide disparity of this group from the former (i.e. the Rinchintong , Pachim and Rongmuk) . This shows highly permeable rocks in these two basins and also that the surface flows available in these two basins are , probably , so little that one kilometre length of the second order stream could cater to the run off needs of 156.82 ha in Ghatta and 122.22 ha in Upper Balason as against only 85.61 ha , 88.89 ha and 85.47 ha in Rinchintong , Pachim and Rongmuk respectively .

Table 3.10 has been deduced by assessing the proportion of the length of each order of the stream to the total length of that .

TABLE 3.10

PROPORTION OF LENGTHS OF STREAMS OF VARIOUS ORDERS TO THE TOTAL LENGTH OF THE STREAM IN THE BASIN

ORDER	GHATTA JHORA	RINCHIN-JHORA	PACHIM JHORA	RONGMUK JHORA	U.BLSON JHORA
	Percentage to the total				
1	69.09	60.81	68.82	76.64	74.61
2	20.00	22.30	19.35	15.69	13.93
3	5.45	6.08	6.45	4.74	5.26
4	5.45	6.08	5.38	2.92	4.95
5	0.00	4.73	0.00	0.00	1.24
TOT	100	100	100	100	100

(Source : Author's own calculation)

As is seen , Ghatta and Pachim basins show similarities in respect of the proportion of length of the various order of the streams to the total length . Rongmuk and the Upper Balason basins show similarities among themselves . The Rinchingtong basin with the least proportion of first order and the highest proportion of second and the higher orders forms a class apart . In Rongmuk and the Upper Balason basins ratio of stream lengths of first order is the highest and that for second order the lowest . This shows severe faults and fractures on account of crushed rocks in these two basins . These two basins are likely to see more subsidence , rock slides and landslides , comparatively speaking . The Rinchintong basin has the lowest proportion of the first order and the highest of the second order , even though , it has the highest incidence of first order streams . This shows that the streams of the first order in Rinchintong basin have the strongest tendency , among all the five basins , to join one another to make the streams of higher orders . On the other hand in the Rongmuk and the Upper Balason basins , they tend to run parallel .

Among the Ghatta and the Pachim basins , despite wide variation in number of streams contained per unit area, (Table 3.7), proportion of lengths of first , second and higher order of the streams to the total length is strikingly similar (69.09 % - 68.82 % , 20 % - 19.35 % and 10.90 % - 11.83 % for first , second and higher orders for Ghatta and Pachim basins respectively) . One wonders why is it so . The density of the streams show highly permeable rocks in Ghatta basin and highly impermeable ones in

Pachim . One explanation may be that despite different nature of rock materials , the pattern of faults and fractures in these two basins are fairly comparable giving same proportion of the lengths of various orders of streams . Surficial forms of erosion , however , are more in Pachim than in Ghatta on account of higher density of streams . Hydrograph of the flow , too , is more acute in Rinchintong giving it higher bed load carrying capacity .

3.4.3 AVERAGE LENGTH OF STREAMS :

Wide variation is seen in the Jhoras in the study area in respect of the average length of streams of various orders . The table 3.11 gives this data .

TABLE 3.11

AVERAGE LENGTH OF STREAMS (Km) IN THE BASIN

(1)

ORDER	GHATTA JHORA	RINCHIN-JHORA	PACHIM JHORA	RONGMUK JHORA	U.BALASN JHORA
1	0.64	0.44	0.63	1.13	0.73
2	1.10	0.66	0.64	0.96	0.63
3	1.00	0.90	1.00	1.18	1.13
4	3.00	3.00	5.00	4.00	4.00
5	0.00	7.00	0.00	0.00	4.00

(Source : Author's own calculation)

Among the first order of the streams the shortest average length (o.44 km) in Rinchintong basin is noteworthy . The Rongmuk basin with the longest average length of its first order streams (1.13 km) makes another spectacular virtue of the study area . The Ghatta and Pachim basins with average length of their first order streams , respectively , 0.64 km and 0.63 km , show a close similarity . The Upper Balason basin with that value as 0.73 km forms a class closer to them .

Despite enormous difference in the over all drainage density in the Ghatta and the Pachim basins (

3.19 km and 5.86 km per sq km respectively) , both show an extraordinary similarity in respect of the average lengths of the first order streams . Another such similarity has earlier been pointed out among these two basins regarding the proportion of lengths of streams of various orders to the total length . The proportion of the lengths of first , second and higher orders of the streams to the total length is 69.09 % - 68.82 % , 20 % - 19.35 % and 10.90 % - 11.83 % for Ghatta and Pachim respectively. Despite the varying nature of the rock material , the localised geological forces acting on the two basins and , consequently , the pattern of faults and fractures in them are fairly comparable. This is the reason for such similarities.

The smallest average length of the first order streams in Rinchintong makes it a basin having the finest drainage texture . The Rinchintong basin shows a dendritic pattern of drainage . Rocks in this basin are the most impervious of all and the soil developed has the least sub - surface conductivity .

The highest average length (1.13 km) of first order streams in Rongmuk basin are, on an average, as long as 2.5 times of those in Rinchingtong. This can be explained by the following statement. In Rinchintong basin every first order stream meets another after it has traversed only about 440 mts of its course whereas in Rongmuk it has to travel as long as 1130 mts to meet another of same or of higher order . Because of their proximity , the quantum and the intensity of the rainfall are roughly comparable . The rainfall pattern can not , therefore

, be the reason for such wide disparity among the two basin of the same catchment. Very clearly the tendency among the first order streams of the Rongmuk river is to travel parallel to one another , comparatively speaking . In respect of average lengths of second order streams , Rinchintong , Pachim and Upper Balason are fairly equal (0.66 km , 0.64 km and 0.63 km respectively) . The two aberrations are Ghatta and Rongmuk with values 1.10 km and 0.96 km respectively . While assessing the significance of the average lengths of the second order streams it must be born in mind that the second order streams are generally located in the middle parts of the slope of the river basins . While Rongmuk maintains its average length (0.96 km) among the highest , what is revealing is the graduation of the Ghatta basin as the holder of the longest second order streams and the stagnation of the Pachim as a basin having the average lengths (0.64 km) almost the lowest (lowest being 0.63 km in Upper Balason). Pachim shows that in its middle slopes too it has similar patterns of the streams as that on its upper reaches . The same is not true for the Ghatta basin . As one descends down from the brim of the basin , in case of Ghatta , one will encounter streams which shall be running longer before changing their order by merging with other similar streams . This shows the strong tendency of the streams in the middle slopes of Ghatta and Rongmuk to run parallel to one another . In the latter , the tendency did exist in case of first order streams located near the brim and was carried down the slope to the second order streams , but in case of latter the streams on the middle slopes developed exaggerated patterns of parallel drainage . This shows

that the faults and fractures in the rock materials in the middle reaches of the slopes are most severe , and roughly comparable among them , in Ghatta and Rongmuk basins . No clear pattern are discernible in average lengths of higher orders .

The most uniform increase in average lengths of streams of various orders is seen in respect of Rinchintong basin . This shows that in this basin the drainage patterns have developed basically on account of the requirements for conduction of the surface run off in the basin .

The fig 3.7 very clearly depicts highest average lengths of the first order of streams in the Rongmuk basin and also as to how the Ghatta basin has almost taken over the Rongmuk in respect of the average lengths of the second order streams in the basin . An almost uniform rate of increase of the average lengths of the streams of the first , second and third order in the Rinchintong basin (0.44 km , 0.66 km and 0.90 km respectively) is also very clearly brought about .

Besides drainage frequency , another important characteristics needing consideration is bifurcation ratio of streams which is discussed next .

3.5 BIFURCATION RATIO :

The bifurcation ratio for all the streams in the study area has been determined and is given in table 3.12.

Average Length of stream

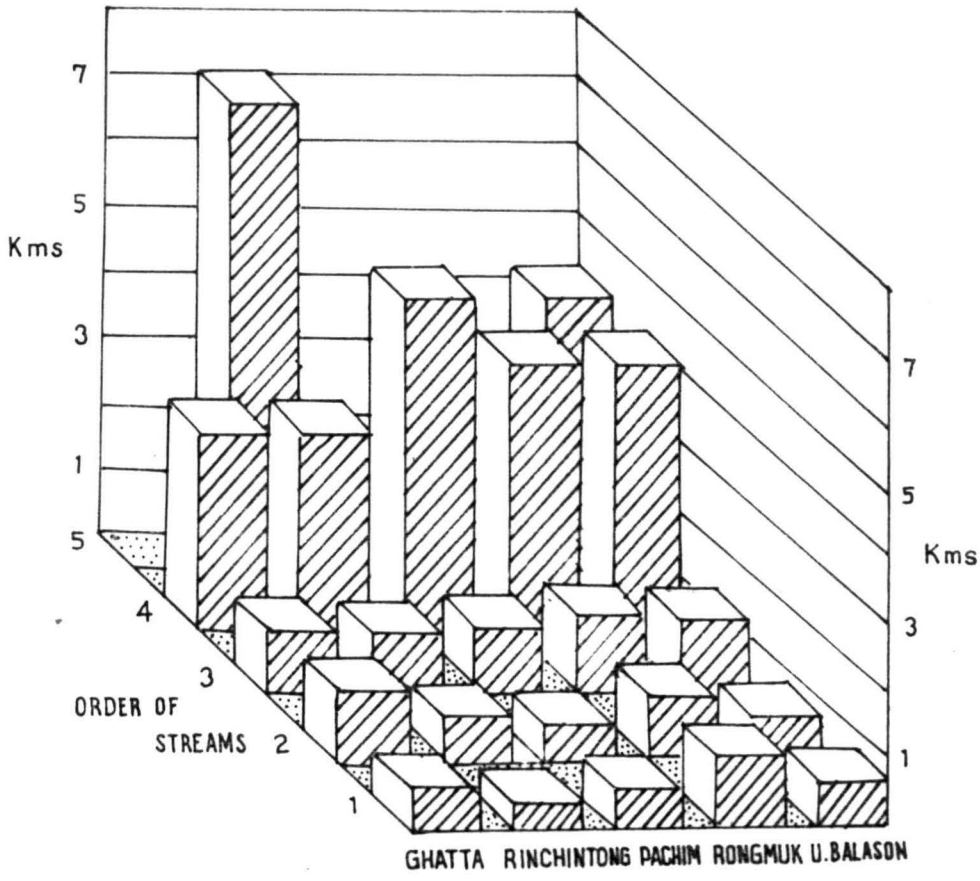


Fig. 3·7

TABLE 3.12

BIFURCATION RATIO OF THE STREAMS

(Rb)

ORDER	GHATTA JHORA	RINCHIN-JHORA	PACHIM JHORA	RONGMUK JHORA	U.BLSON JHORA
1	5.90	4.08	3.61	4.13	4.65
2	3.30	5.00	4.67	4.10	4.73
3	3.00	3.33	6.00	5.50	3.75
4	0.00	3.00	0.00	0.00	4.00
5	0.00	0.00	0.00	0.00	0.00

(Source : Author's own calculation)

As is seen the bifurcation ratio for the first order streams is the highest for Ghatta Jhora (5.90) and the lowest for Pachim (3.61) .The Rinchintong , Rongmuk and Upper Balason make a comparable group with their values , respectively , as 4.08 , 4.13 and 4.65 . In case of Pachim , number of first order streams is 3.61 times that of second order while in case of Ghatta this figure is 5.90 times . In other words , in case of Ghatta Jhora as many as 5.90 streams , on an average , feed each one of the second order streams whereas in case of Pachim only 3.61 streams do so . Since basins with lower bifurcation ratios are known to have acute shape of hydrographs , drainage of surface run off from first order streams shall be the quickest in Pachim and the slowest in Ghatta . That makes basin area of Pachim more susceptible to sheet and rill erosion . Likewise conclusions can be drawn for streams of other orders too . In case of Pachim and Rongmuk the highest bifurcation ratio of third order basins (6.00 and 5.50 respectively) is noteworthy . This shows that in respect of third order streams they have the strongest tenancy to run parallel to one another. The bifurcation ratio of streams of various orders has also been depicted in Figure 3.8.

Bifurcation Ratio (stream order)

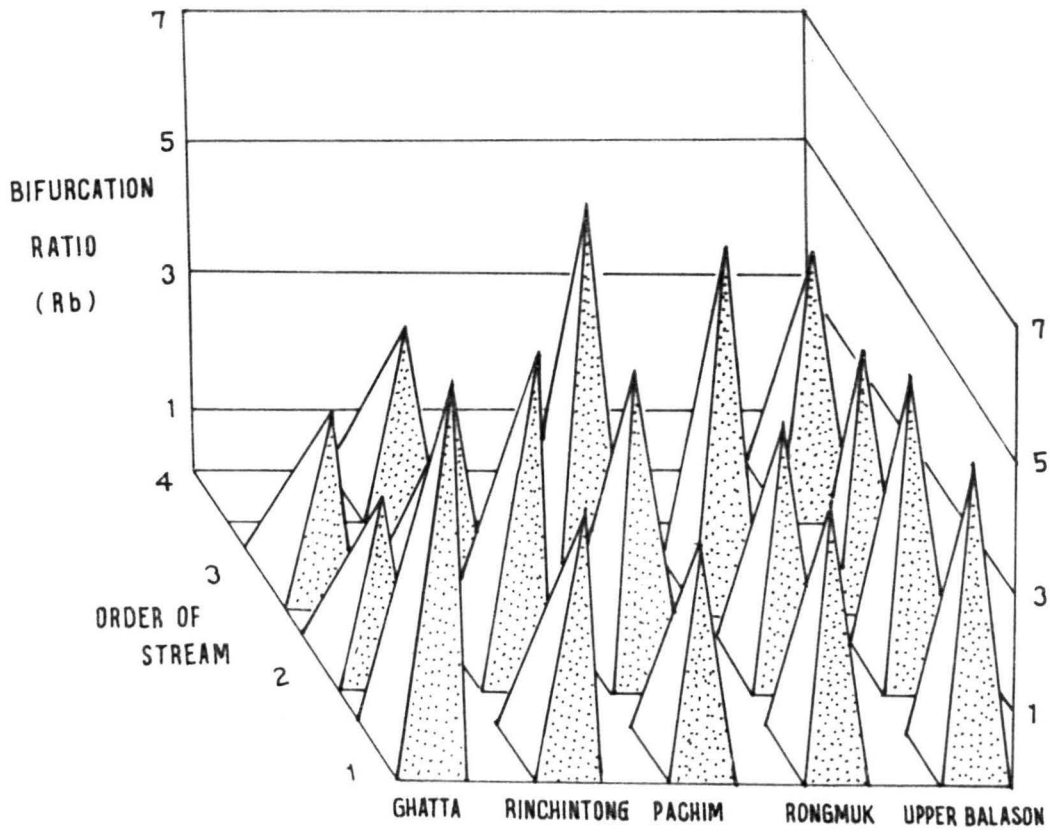


Fig. 3·8

The bifurcation ratio for the basin has also been calculated . The determination of bifurcation ratio of basins has been done following standard techniques (Chorley , 1971) . The bifurcation ratio of Rongmuk (5.4026) is the highest and that of Ghatta the lowest (3.7532) (Fig 3.9) . The hydrograph of Ghatta basin is, therefore , to the most acute and that for Rongmuk the flattest of all . The results are however not exactly comparable , quantitatively , as the drainage density of Ghatta (3.19 km per sq km) is lower than that of Rongmuk (7.40 km per sq km).

3.6 STREAM LENGTH RATIO :

Like bifurcation ratio another important ratio needing attention for exploration of characteristics of basin is the stream length ratio. The stream length ratio in the study area is also quite interesting . This is given in Table 3.13.

TABLE 3.13

STREAM LENGTH RATIO IN DIFFERENT BASINS

(Rl)

ORDER	GHATTA JHORA	RINCHIN-JHORA	PACHIM JHORA	RONGMUK JHORA	U. BALASON JHORA
1	1.00	1.00	1.00	1.00	1.00
2	0.29	0.37	0.28	0.20	0.19
3	0.27	0.27	0.33	0.30	0.38
4	1.00	1.00	0.83	0.62	0.94
5	0.00	0.78	0.00	0.00	0.00

(Source : Author's calculation)

As is seen from table 3.13 , stream length ratio for second order streams is the highest for

Bifurcation Ratio in the Basins

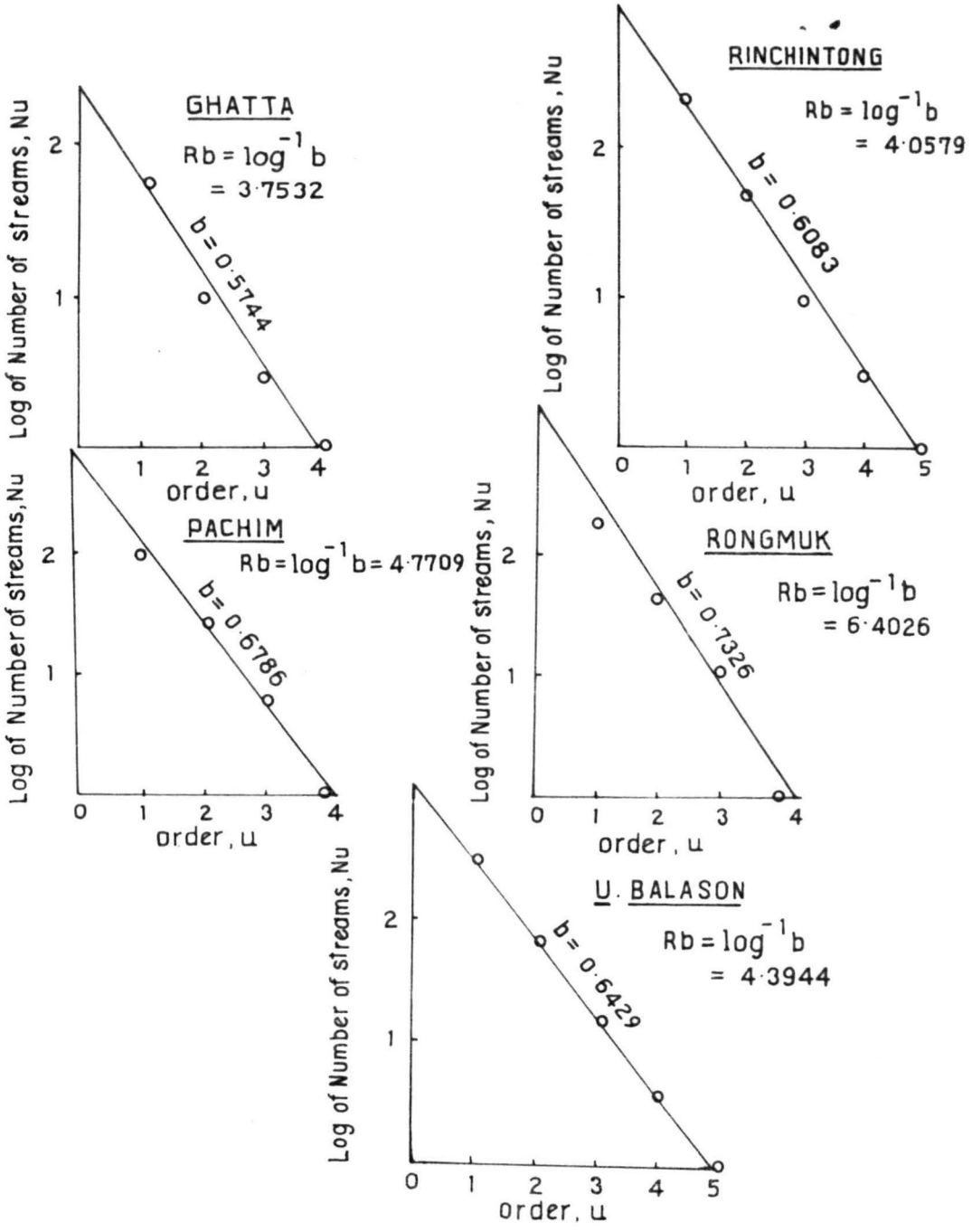


Fig. 3·9

Rinchintong (0.37) and the lowest for Upper Balason (0.19) with Rongmuk very close to it (.20) . The Ghatta and Pachim show a close similarity with their values , respectively , 0.29 and 0.28 . Three distinct categories are visible . The lengths of second order streams are 20 , 30 and 40 percent of that of first order in Rongmuk and Upper Balason , Ghatta , and Pachim respectively . Similarly , these values for third order streams are 30 percent for Ghatta , Rinchintong , Pachim and Rongmuk whereas that for Upper Balason is 40 percent. The values for higher order streams are almost similar . In case of Upper Balason , stream length ratio for second order stream is the lowest and that for third order stream the highest. This is on account of the shape of the basin which is fan like.

From the table 3.13 and Fig. 3.10, three distinct groups in stream length ratio of second order streams have been clearly brought out . The lowest and the highest stream length ratios for second and third order streams of Upper Balason are also discernible. The highest stream length ratio of second order streams in Rinchintong shows the greatest tendency of first order streams to produce those of higher orders in this basin . This is the least in, both, Rongmuk and Upper Balason indicating the strongest tendency of first order streams to run parallel .This shows the severest faults and fractures in these basins . By the same reason, Rinchintong has the least intensity of faulting and fracturing . This makes Rongmuk and Upper Balason most sensitive for slides , sinking , rockfall and similar soil degradation processes and Rinchintong the most sensitive for

Stream length ratio

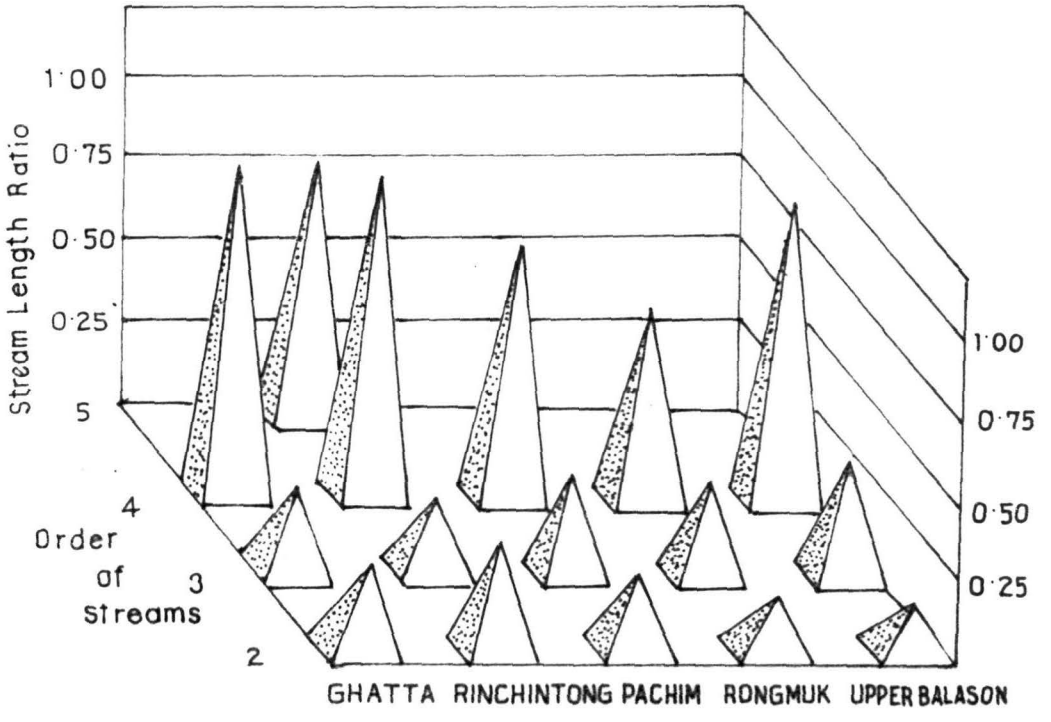


Fig. 3·10.

surficial forms of soil erosion The Ghatta and Pachim basins form the intermediate category . Extremely low drainage density in case of Ghatta (3.19) as against Pachim (5.86) , however , imparts some degree of unreliability in their quantitative comparison . It appears that the pattern of faulting and fracturing is similar in these two basins but more permeable rocks in Ghatta has impeded development of drainage to the extent of that in Pachim. It can be safely concluded that in Pachim , surficial forms of soil degradation , and in Ghatta , sinking and sliding , are the most prominent .

3.7 SINUOSITY :

The sinuosity of the five channels in the study area has been determined by measuring the axial distance and the lengths of the thalwegs (DURY , 1969) as seen from the satellite imagery dated 26th January , 1996 . The results are given in the table 3.14.

TABLE 3.14

SINUOSITY OF THE RIVERS IN THE BASIN

River	channel	Thalweg	Sinuosity
	km	km	
Ghatta	3.50	4.10	1.1714
Rnchnto	9.90	13.45	1.3586
Pachim	6.50	6.85	1.0538
Rongmuk	7.90	7.95	1.0063
U.Balas	8.80	9.45	1.0739

(Source : Satellite imagery dated 26-01-96)

As is seen , streams are not much sinuous in comparison to level country where , usually , a sinuosity of 1.5 is taken as the minimum value for accepting the

river as a meandering one (Dury , 1969) . But one must keep in mind that rivers under study are located in hilly terrain (gradient from 15 to 22 percent ; Table 3.1) and can not meander as those in the level country . The sinuosity of rivers in the study area , howsoever small , presents some interesting features , nevertheless .

The Rinchintong river is the most sinuous , the least being the Romgmuk . The Ghatta forms the second most sinuous river . The sinuosity of Rinchintong is explainable in view of the highest density of drainage lines (9.38 nos per sq km) and the lowest average lengths of the lower order streams both indicative of the toughest and the least faulted and fractured rock material in its basin . The river could not cut its way straight through . The sinuosity of Ghatta is , however , quite surprising . The Ghatta basin has the lowest number of drainage lines (4.2 nos per sq km) and the lowest drainage density (3.19), the highest average length of the second order streams and the third highest average length of the first order stream . All these indicate parallel drainage pattern .

The sinuosity of the Rongmuk river is seen the lowest at 1.0063 . The Upper Balason and the Pachim make a close group with their values , respectively , 1.0739 and 1.0538 . The sinuosity of rivers is associated with turbulence in the flow of stream . More sinuous the stream , more is the agitation in flow and , consequently , more is the suspended load . Any soil particle dislodged from its position , if once reaches a turbulent sinuous stream of hilly terrain , has very little

chance to get deposited in way . Thus, Ghatta and Rinchintong have higher carrying capacity . Besides this , sinuous stream are very actively working on obstruction in their way , are always trying to straighten their courses leading to higher incidence of bank failures . Field verification shows higher instances of bank failures along these two rivers . This is , at least in part , on account of their higher sinuosity , specially , in the lower reaches (Fig. 3.11).

Another spectacular characteristics of streams is revealed if one computes their sinuosity from the topo sheet (survey in 1931) . The result is given in Table 3.15.

TABLE 3.15
SINUOSITY OF THE RIVERS TOPO SHEET

River	channel km	Thalweg km	Sinuosity
Ghatta	3.50	3.95	1.1286
Rnchnt	9.90	10.15	1.0253
Pachim	6.50	6.75	1.0385
Rongmuk	7.90	8.45	1.0696
U.Balson	8.80	9.30	1.0568

(Source : Survey of India topo sheet , 1931)

As is seen , Rinchintong river was the least and Ghatta the most sinuous in 1931 (Fig 3.12 and Table 3.15) . The other three rivers form the intermediate category . A comparison of the lengths of the thalweg as available from the toposheet (1931) and from the satellite imagery (26th January , 1996) reveals another interesting point (Fig. 3.13). Table 3.16 tabulates the comparative figures .

SINUOSITY OF STREAM (3rd order & above)

(based on satellite imagery, 1996 .)

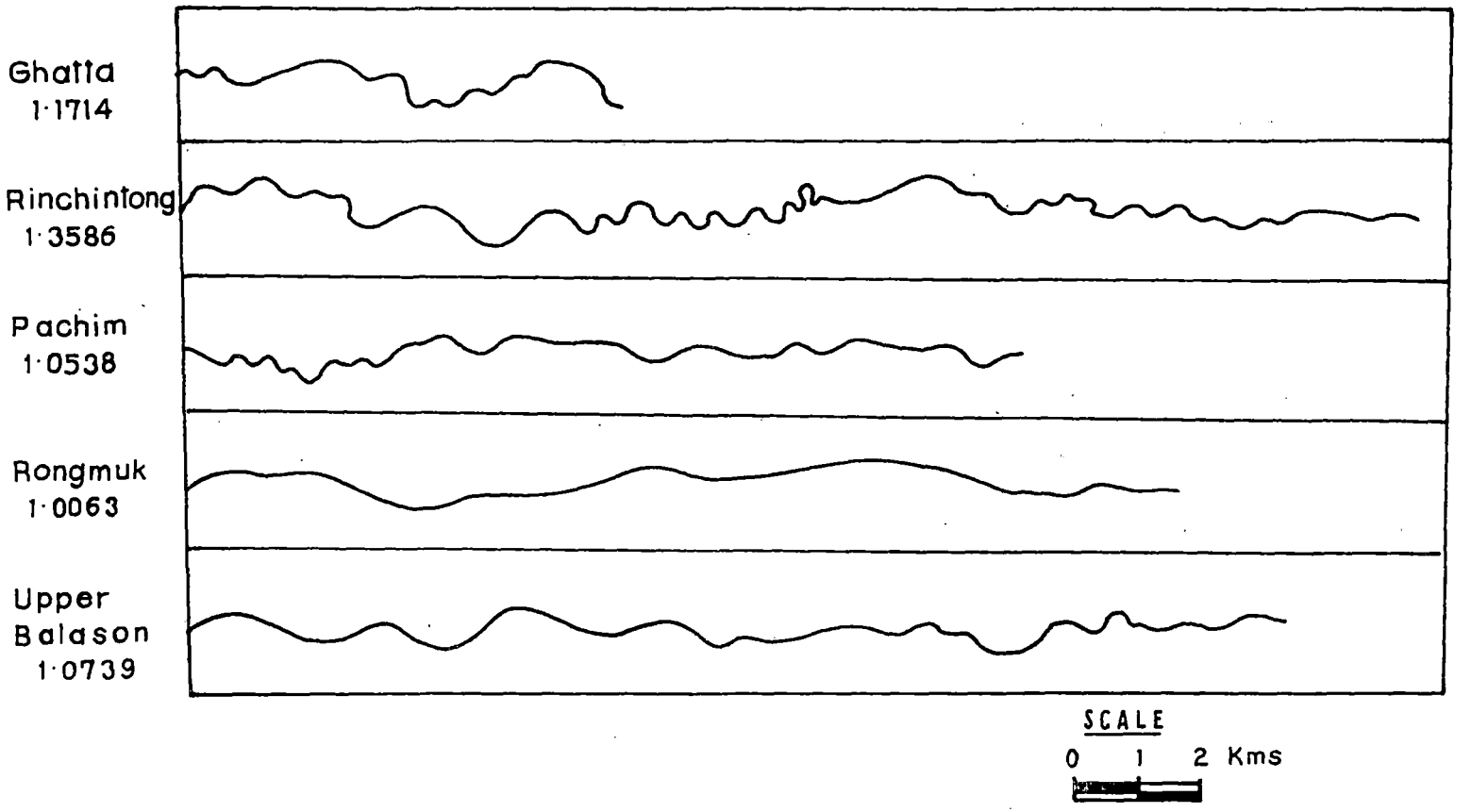


Fig. 3·11

SINUOSITY OF STREAM (1931)

(Based on S.O.I. Toposheet , 1931)

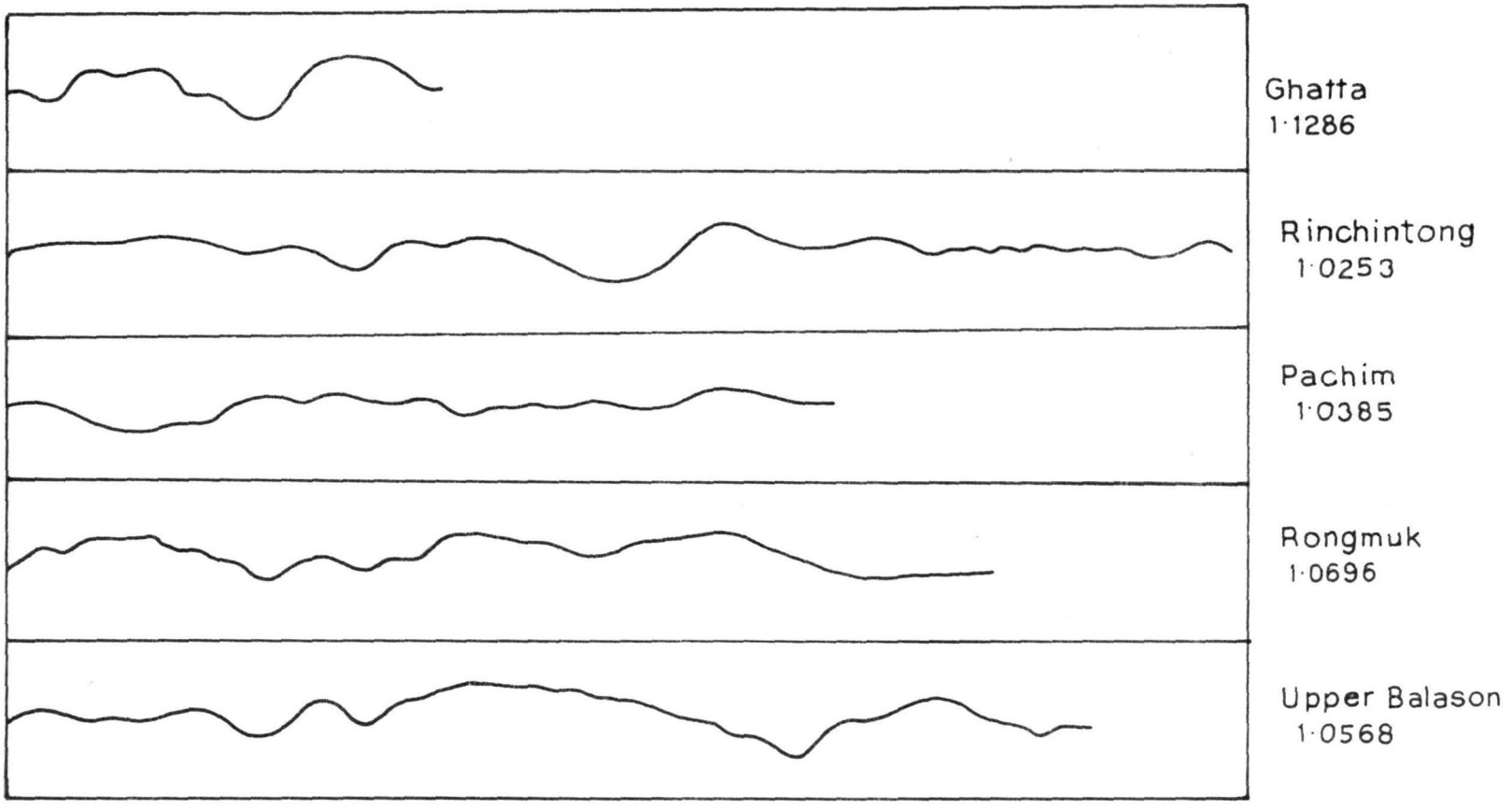


Fig. 3·12.

Stream Length vs Thalweg

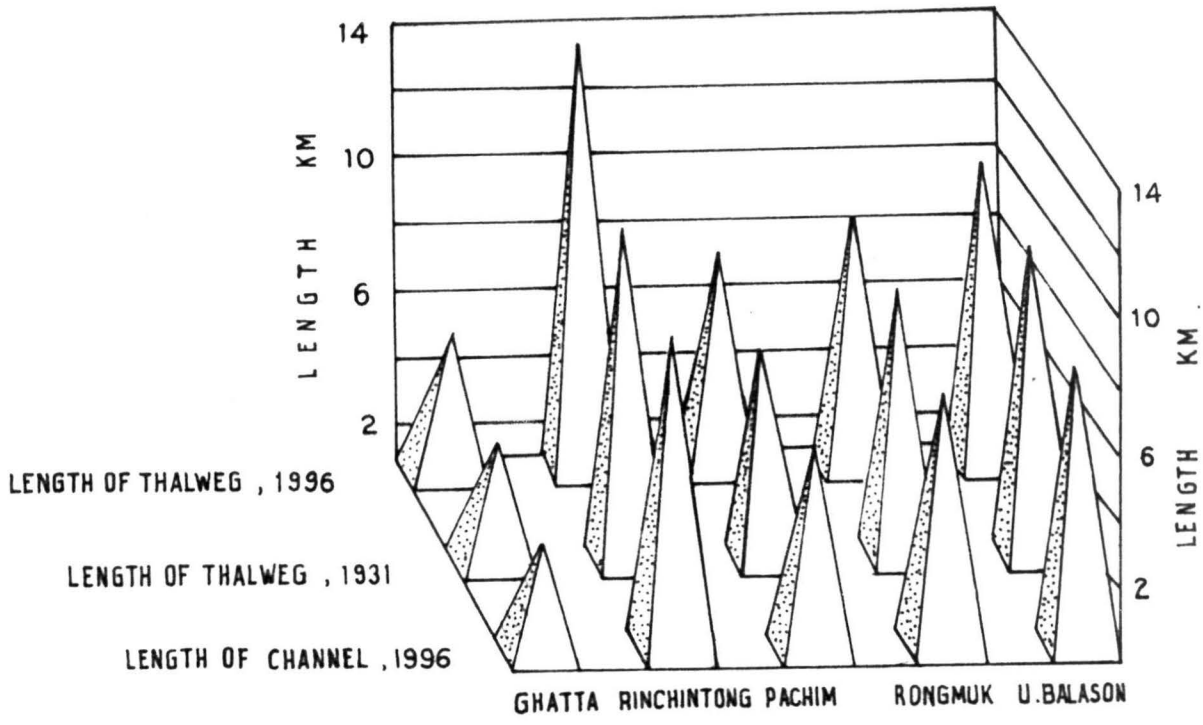


Fig. 3·13

SINUOSITY

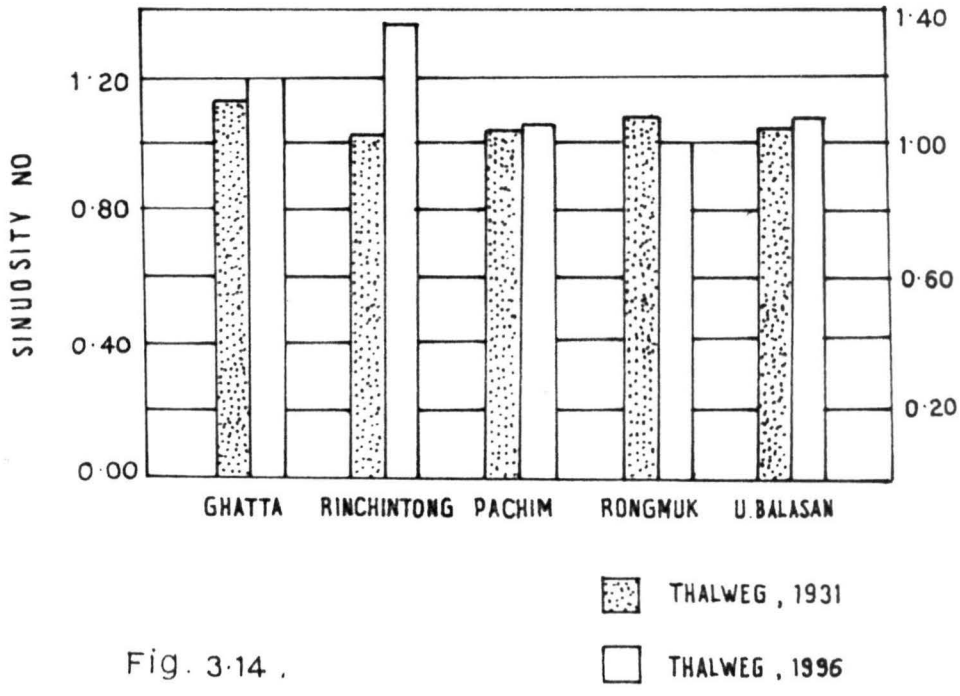


Fig. 3·14 .

TABLE 3.16

SINUOSITY OF THE RIVERS IN THE BASIN

River	Channel	Thalweg 1931	Thalweg 1996	Sinuosity 1931	Sinuosity 1996
	km	km	km		
Ghatta	3.50	3.95	4.10	1.1286	1.1714
Rnchnt	9.90	10.15	13.45	1.0253	1.3586
Pachim	6.50	6.75	6.85	1.0385	1.0538
Rongmuk	7.90	8.45	7.95	1.0696	1.0063
U.Balsn	8.80	9.30	9.45	1.0568	1.0739

(Source : Author's calculation from Survey of India topo sheets and Satellite imagery date 26th January , 1996)

The Fig. 3.14 represents the comparison of the sinuosity of the five rivers in the study area in 1931 and 1996 . The highest increase in the length of thalweg during this period is seen in Rinchintong (10.15 km to 13.45 km) . This is an increase of about 33 percent . Increase in Ghatta has been only 4 percent . Increase in Pachim and Upper Balason is insignificant whereas in Rongmuk , there is a 6 percent decrease (from 8.45 km in 1931 to 7.95 km in 1996).

To understand sinuosity of channels one has to take help of the Manning's formula which defines the flow of water in the open and closed channels . The formula is given below : -

$$V = 1/n \; R^{2/3} \; S^{1/2}$$

where ,

V is velocity of flow in mt per sec.

n is Manning's roughness coefficient for the type of the channel .

R is hydraulic radius or hydraulic depth of the flow and is given by A / P where

A is cross sectional area of the flow in sq. mt.

P is the wetted perimeter of the flow in meters .

S is the slope of the flowing liquid surface (mt per mt of the liquid of the surface) or sine of slope of the water surface .

It can be proved that in an open channel a given peak discharge shall decide the values for V , R and S and , if the peak discharge is altered , these values shall be redefined . The n being a constant , in case of an open channel , an increase in the peak discharge shall also result in an increase in the values of V , R and S , and vice - a - versa . An increase in the value of S shall be a high energy situation , and consequently , more stressful condition . The river ,in such a situation , shall have a strong tendency to grow sinuous to increase effective length of flowing water surface so that energy gradient goes down as much as possible . This shall result in lengthening of thalweg . Thus higher peak discharge shall tend to make rivers more sinuous and vise - a - versa .

The Rinchintong river drains a vast tract of forest (916 ha out of its total 2825 ha being forest) concentrated on its upper reaches . Pachim and the Rongmuk , on the other hand , have only 5 percent and 19 percent of their areas under forest cover, respectively, in upper parts of their basins . The entire forest area , specially that falling in Rinchintong basin , lying close to human habitation such as Sepoydhura , Tung

, Garigaon , Aringale , Dilaram , and Chatakpur Siding has been , and still is , under the most severe biotic pressure among all forest patches in the study area. It appears that this denudation has caused tremendous increase in peak discharge of Rinchintong and has , in turn , caused greater degree of sinuosity .

Increase in sinuosity of Ghatta river is on account of Kurseong town , whose population has increased from 7451 in 1931 (Census of India , 1931) to 27,419 in 1991 (Census of India , 1991) with consequent deforestation, increased runoff , and increased peak discharge from the basin. The decrease in sinuosity of Rongmuk river is , however, quite inexplicable . One reason for reduction of sinuosity is lessened peak discharge due to large scale water harvesting in Senchal forest area . Huge artificial lakes have been constructed and as many as 40 streams originating from forest and feeding Rongmuk have been tapped for supplying water to Darjeeling . Degradation of Senchal forest is also of very high order , and , had the water been not tapped , one would have expected peak discharge of this river , too , to have gone up , and this river too , to have grown more sinuous . This increased sinuosity would have , probably , been catastrophic and areas in and around Milling tea garden would have been sinking much faster than they do now as the garden is located on a site having highly faulted and fractured rocks .

3.8 CROSS AND COMPOSITE PROFILE :

The profile of an area gives a comprehensive over all view of it . The general nature of terrain and the major land use patterns become visible from such profiles if the transect is carefully chosen and passes through representative area .

3.8.1 CROSS PROFILES :

Two cross profiles , one in east - west and other in north - south direction , are depicted , respectively , in Fig. 3.15 and 3.16 . The east - west cross profile shows how degradation of slopes has progressed to far greater extent on eastern side than that on western side of basin . This further shows as to how the entire area is like a tilted saucer , the direction of the tilt being south - western . As is seen , upper reaches of basin are covered with forest below which entire basin is full of tea gardens . Any land which is not usable for cultivation of tea , is generally seen having wild scrub growth coming on its own . This is further heavily grazed and browsed and dominated only by non-palatable thorny bushes . These scrubs are mostly found on steep slopes subjected to extensive sheet erosion . The north - south cross section shows that the slope descends down from north to south . This also shows occurrence of tea gardens on all milder slopes and scrubs on steeper ones .

3.8.2 COMPOSITE PROFILE :

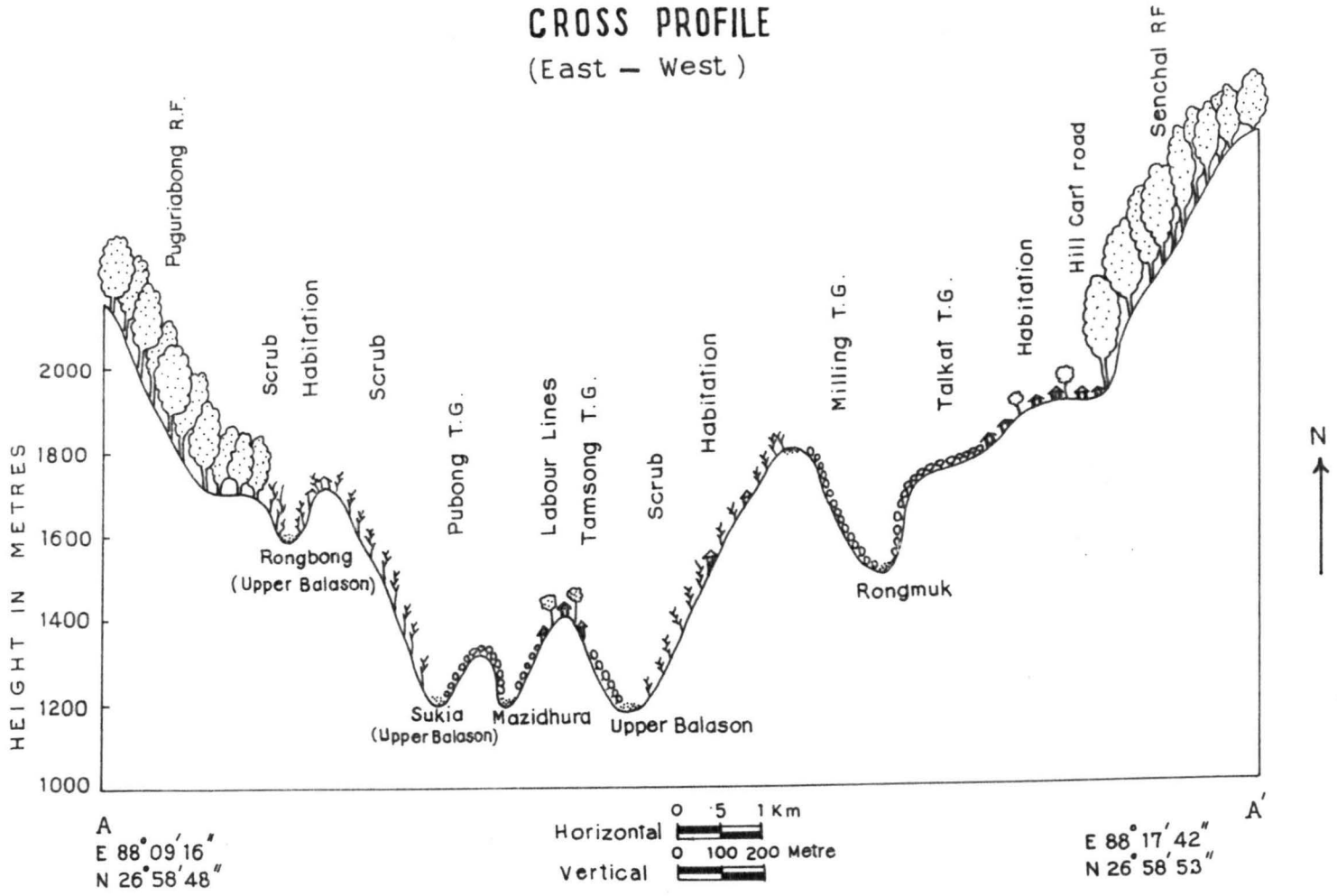

CROSS PROFILE
(East – West)
HEIGHT IN METRES
2000
1800
1600
1400
1200
1000
Puguriabong R.F.
Scrub
Habitation
Scrub
Pubong T.G.
Labour Lines
Tamsong T.G.
Scrub
Habitation
Milling T.G.
Talkat T.G.
Habitation
Hill Cart road
Senchal RF
Rongbong
(Upper Balason)
Sukia
(Upper Balason)
Mazidhura
Upper Balason
Rongmuk
N
A
E 88°09′16″
N 26°58′48″
A′
E 88°17′42″
N 26°58′53″
Horizontal 0 .5 1 Km
Vertical 0 100 200 Metre

Fig. 3·15

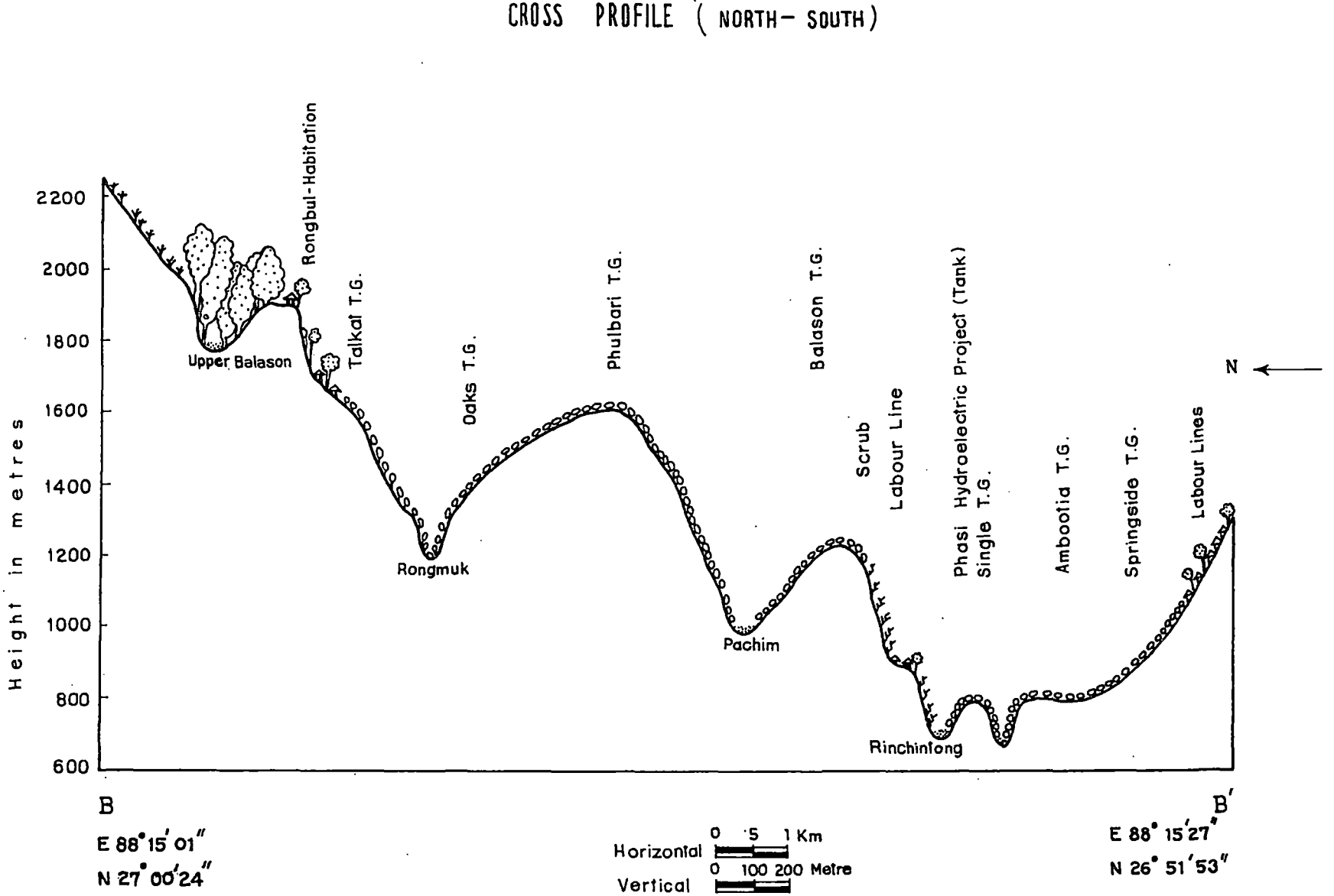

CROSS PROFILE (NORTH– SOUTH)
Height in metres
2200
2000
1800
1600
1400
1200
1000
800
600
Upper Balason
Rongbul-Habitation
Talkat T.G.
Oaks T.G.
Rongmuk
Phulbari T.G.
Pachim
Balason T.G.
Scrub
Labour Line
Phasi Hydroelectric Project (Tank)
Single T.G.
Rinchinfong
Ambootia T.G.
Springside T.G.
Labour Lines
N
B
E 88°15'01"
N 27°00'24"
B'
E 88°15'27"
N 26°51'53"
Horizontal 0 5 1 Km
Vertical 0 100 200 Metre

Fig. 3·16.

The composite profile shows that the slopes are steeper in lower parts than those in upper parts of the basin (Fig 3.17) . The length of slopes are shorter in lower parts whereas these are more dissected upwards .

3.9 HYPSOMETRIC CURVE :

The cross and composite profiles of an area give a general and qualitative account of slope development. A more quantitative and definitive account is obtained from Hypsometric curves of the study area.

From the hypsometric curve it is seen that the basins can be grouped into two :- (i) Ghatta : Hussain - Pachim -Rongmuk and , (ii) Rinchintong - Upper Balason . There is marked similarity between curves of Upper Balason and Rinchintong on one hand and those of Ghatta - Hussain , Pachim, and Rongmuk on the other. The contour lines representing 25 , 50 and 75 percent of basin area are shown in Figure 3.18 and are also given in Table 3.17.

TABLE 3.17

PERCENTAGE AREA OF BASINS AND CORRESPONDING CONTOURS

AREA IN PERCENTAGE	CORRESPONDING CONTOUR IN BASIN IN MT				
	GHATTA HUSSAIN	RINCHINGTONG	PACHIM	RONGMUK	UPPER BALASON
0	2060	2450	2500	2500	2400
25	1290	1930	1600	2020	2030
50	980	1580	1230	1490	1730
75	800	1290	1030	1180	1440
100	550	550	700	800	800

(Source : Author's own calculation)

Composit Profile

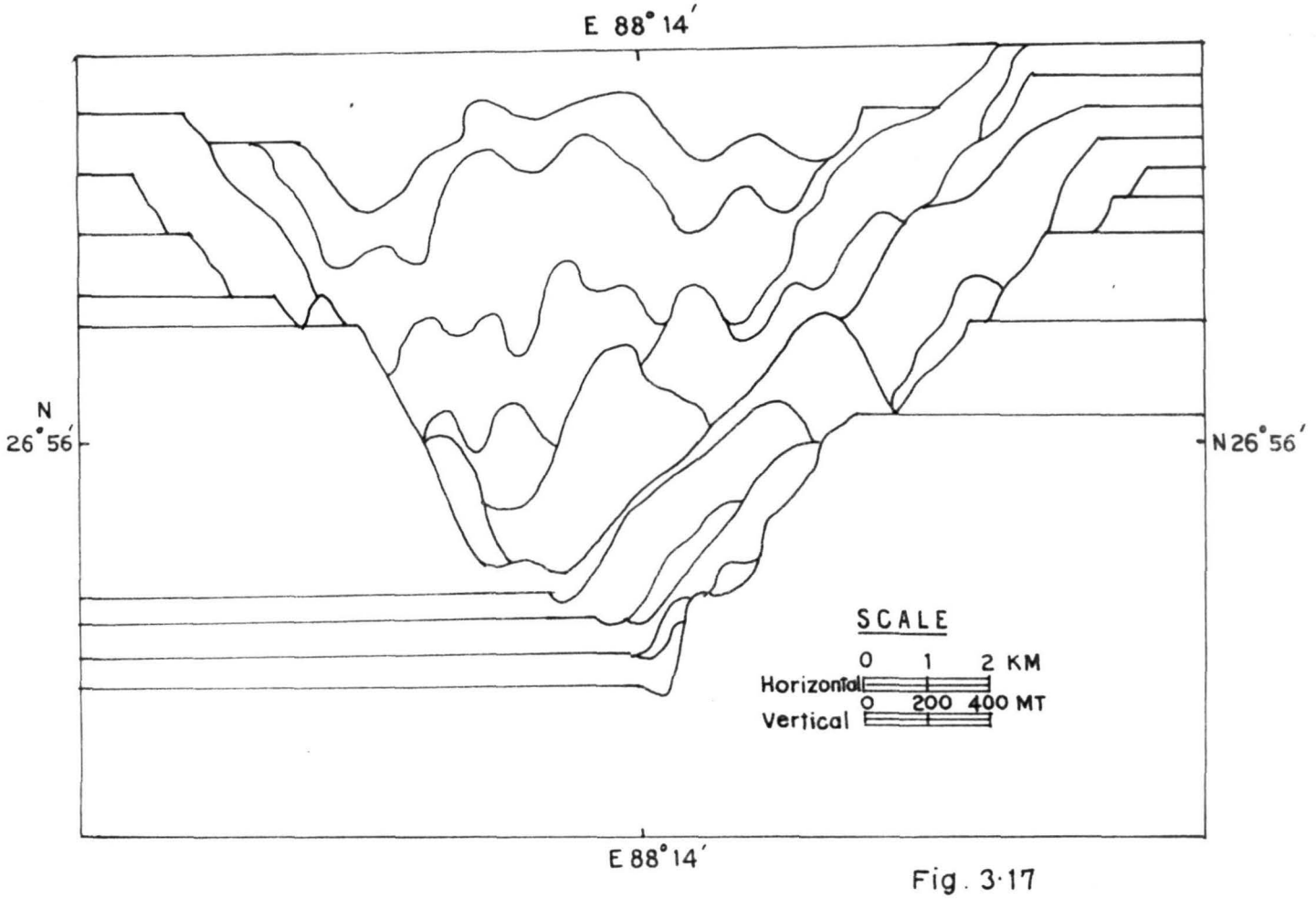


Fig. 3·17

Hypsometric Curve

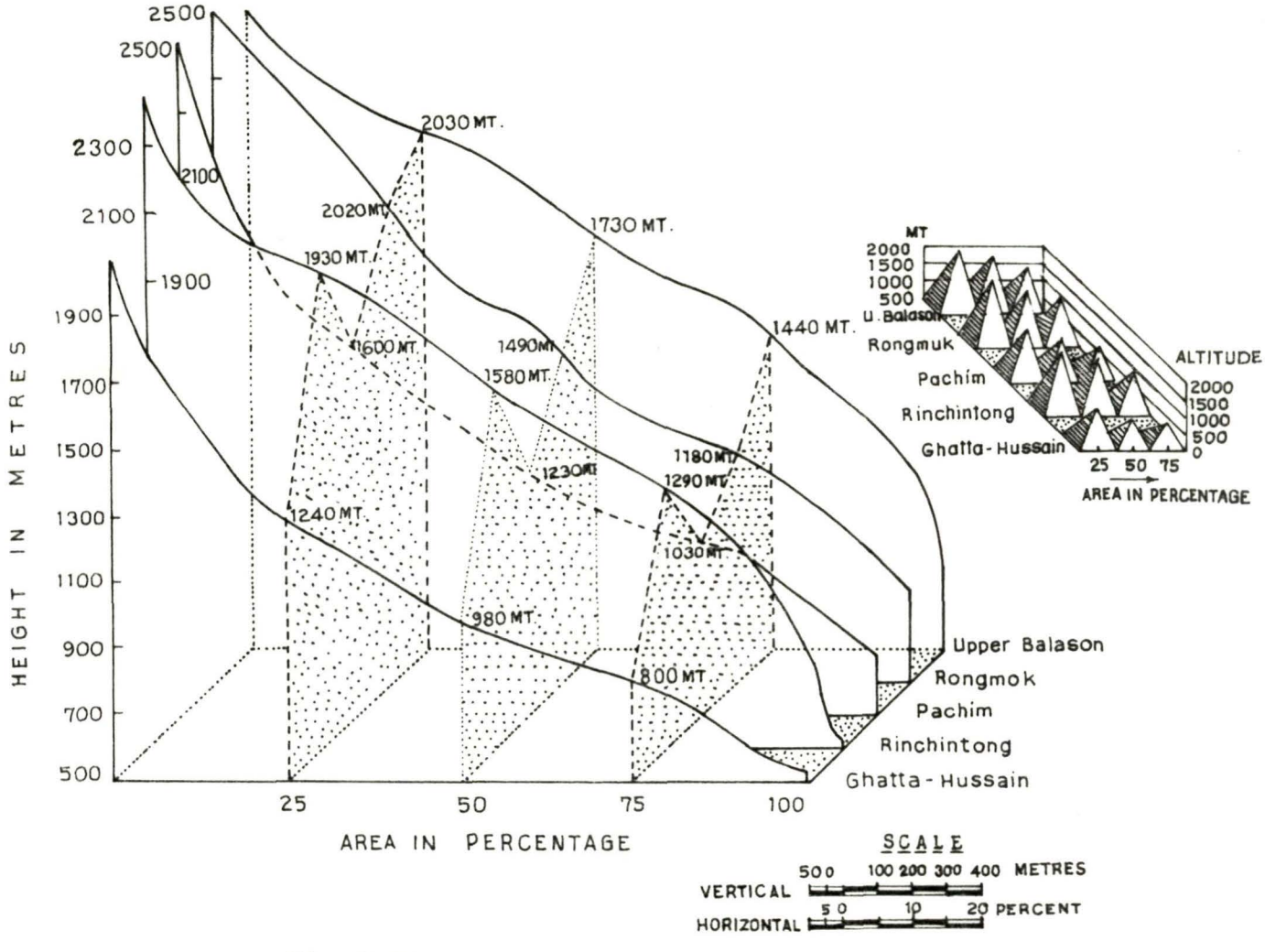


Fig. 3·18

The contour line representing 25 percent top most area of the basin passes at 1290 mt and 1930 mt in case of Ghatta - Hussain and Rinchintong rivers, respectively. This difference for 50 and 75 percent areas is 600 mt and 490 mt respectively . The difference in altitudes of the topmost points of these two basins is 390 mt ; the latter having the higher value . Had distribution of relief been uniform , the difference in contour lines representing 25 , 50 and 75 percent areas from top down would have been , roughly , 300 mt , 200 mt , and 100 mt respectively . The actual difference is higher than the hypothetical difference . A similar comparison of Ghatta - Hussain can be easily done with Upper Balason with like conclusions . This shows relatively younger stage of river development in the Rinchintong - Upper Balason group . A comparison of individual rivers of Ghatta : Hussain - Pachim - Rongmuk group among themselves shows that corresponding differences are not that acute .

As is revealed from the shape of curves (Fig. 3.18) , the basin of the Ghatta - Hussain is past equilibrium stage heading to the maturity . This will also be quite interesting to compare maturity of basins as against that of Ghatta - Hussain . To achieve this , relief of individual basins have been distributed within its lowest and highest points at the same proportion as in Ghatta - Hussain .

TABLE 3.18

MATURITY OF BASINS : GHATTA VIS-A-VIS OTHERS

(Contours and difference in metres)

Rivers	Contour	Area of basin in percentage from top down				
		0	25	50	75	100
Ghatta	Actual	2060	1290	980	800	550
Rinchin gtong	Actual	2450	1930	1580	1290	550
	Calcula ted	2450	1481	1082	873	550
	Differe nce	0	449	498	417	0
Pachim	Actual	2500	1600	1230	1030	700
	Calcual ted	2500	1600	1204	1006	700
	Differe nce	0	0	26	24	0
Rongmuk	Actual	2500	2020	1490	1180	800
	Calcula ted	2500	1633	1276	1089	800
	Differe nce	0	387	214	91	0
Upper Balason	Actual	2400	2030	1730	1440	800
	Calcula te	2400	1584	1248	1072	800
	Differe nce	0	446	482	368	0

(Source : Author's own calculation)

A look at the Table 3.18 reveals that there are striking similarities between Rinchintong and Upper Balason river basins . The differences in actual and calculated contours corresponding to 25 , 50 and 75 percent of the areas of basin are 449 mt , 498 mt , 417 mt for Rinchintong and 446 mt , 482 mt and 368 mt for Upper Balason basins . On the other hand , these differences for Pachim are 0 mt , 26 mt and 24 mt for 25 , 50 and 75 percentages of areas , respectively . This shows that stage of development of river basins of Ghatta - Hussain and

Pachim are very close to one another and both are past the stage of maturity . As against this , stage of development of Rinchintong and Upper Balason basins are , relatively , young . The Rongmuk river basin falls in between (Fig 3.18) .

Attempt has been made to calculate Percentage Hypsometric Curve for river basins as done following standard techniques used by Strahler (Chorley , 1971) .

TABLE 3.19

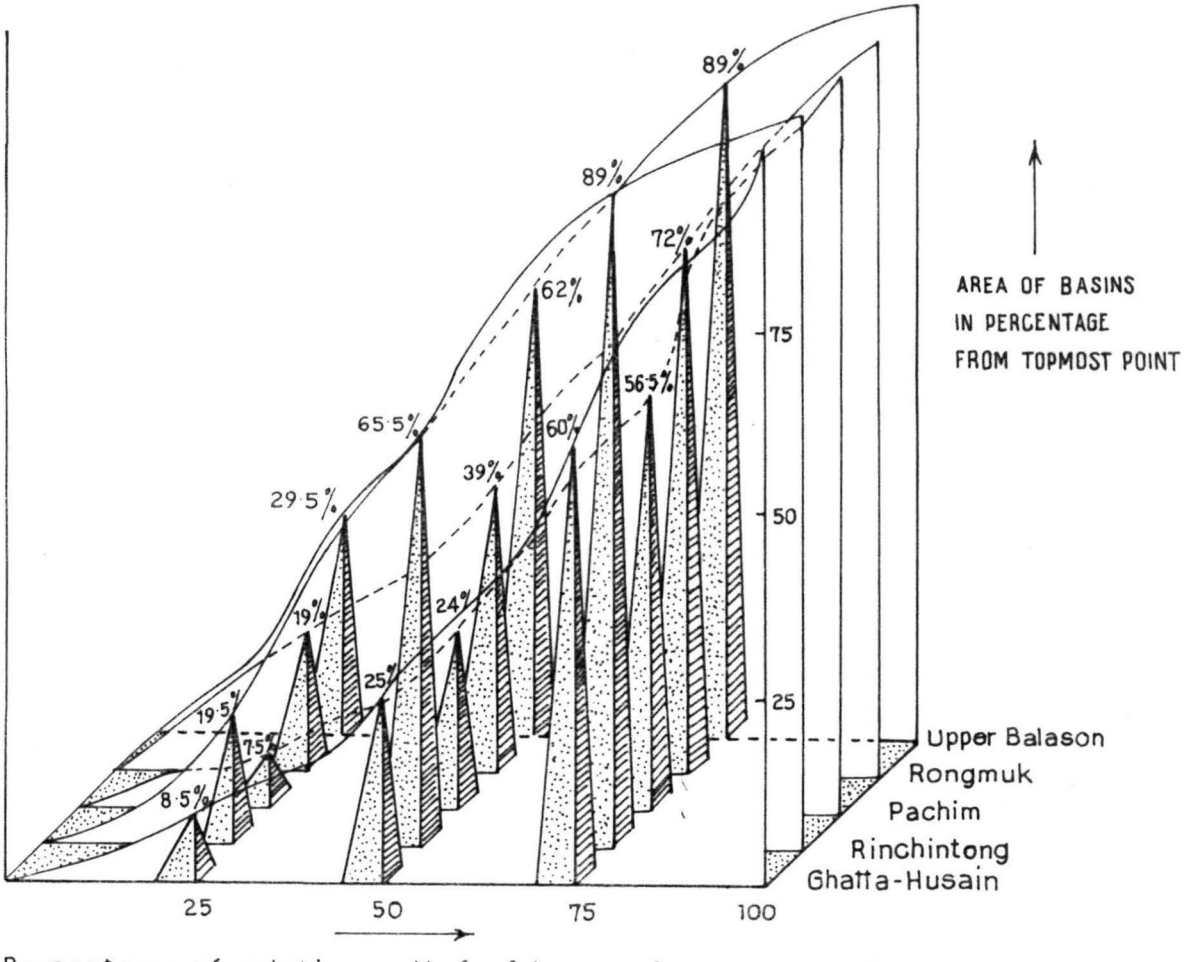
PERCENTAGE HYPSOMETRIC CURVE

% rel. relief top down	Area of basin in percentage				
	Ghatta	Rnchntong	Pachim	Rongmuk	U.Balson
25	8.5	17.5	7.5	19.0	29.5
50	25.0	55.5	24.0	39.0	62.0
75	60.0	89.0	56.5	72.0	89.0

(Source : Author's own calculation)

It is seen that Ghatta - Hussain and Pachim basins have passed the Equilibrium (mature) stage and are heading towards Monadnock phase of the basin degradation (Fig 3.19) . The Rinchintong and Upper Balason basins are in Inequilibrium (young) stage of basin degradation . The Rongmuk basin falls in between .

Relative Hypsometric Curve



SCALE

VERTICAL & HORIZONTAL 50 10 20 PERCENT

Fig. 3·19

3.10 RELATIVE RELIEF :

As is seen from Fig 3.20 , spots of very high relative relief (more than 500 mt per sq km) are located , on northern side , very close to Lepchajagat encompassing northern parts of Pubong and Tomsong tea gardens ; on eastern side , about half km south of Rongbul close to Talkat tea garden , and in between Sonada and Gorabari etc. The patch of high relative relief between Gorabari and Sonada is located on Hill Cart road. Extensive areas are under high relative relief (400 - 500 mt per sq km) . On north western side , it sprawls over Pubong , Pulungdong , Tamsong , Simrikpani , Dooteria , and Avongrove tea gardens and Ghoom Simana reserve forest . This part has a low drainage density (3.5 to 4.5 ; Figure 3.4) which makes it slide prone . In fact an active huge landslide is located right inside these zones close to Lepchajagat . Due to its effect bench of road connecting Ghoom to Sukiapokhari is subsiding . High relative relief is also encountered in Talkat , Rongmuk , Mandakoti , Oaks , Dilaram , Nahar and Singel tea gardens . In general northern half of study area has higher concentration of higher relative reliefs in comparison to southern half making the former more difficult , more erosive , and less productive than the latter . Most of the best tea gardens are located in southern half whereas north western part has very few of them .

Different zones , too , have been classified with regard to weighted value of relative relief (Fig 3.21) . As is seen from this , lower middle zones of Upper Balason , upper

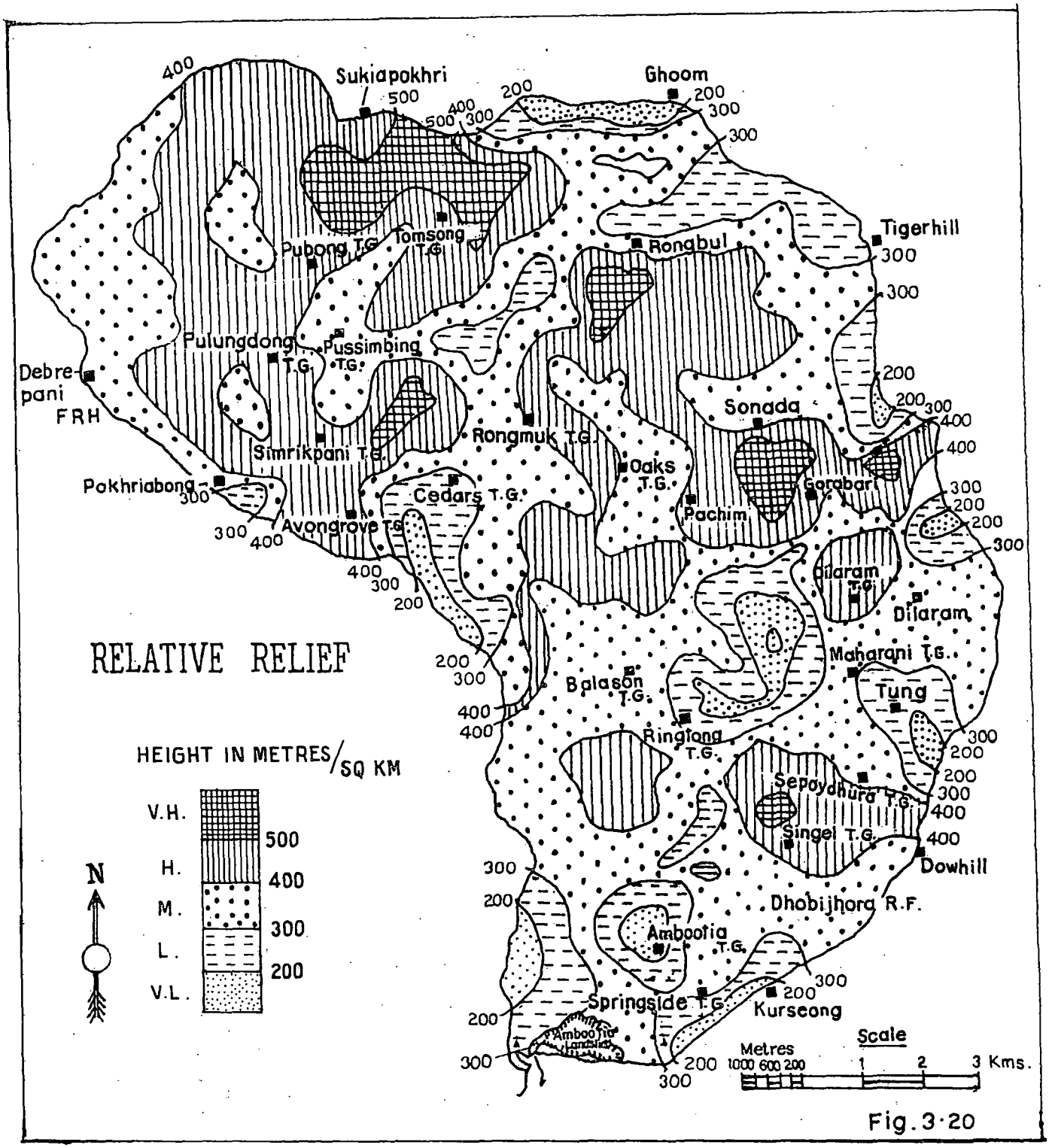

RELATIVE RELIEF
HEIGHT IN METRES/SQ KM
V.H. 500
H. 400
M. 300
L. 200
V.L.
N
Sukiapokhri
Ghoom
Tigerhill
Rongbul
Pubong T.G.
Tomsong T.G.
Pulungdong T.G.
Pussimbing T.G.
Debrepani FRH
Sonada
Rongmuk T.G.
Simrikpani T.G.
Pokhriabong
Cedars T.G.
Oaks T.G.
Gorabari
Pachim
Avongrove T.G.
Dilaram T.G.
Dilaram
Maharani T.G.
Balason T.G.
Tung
Ringtong T.G.
Sepoydhura T.G.
Singel T.G.
Dowhill
Dhobijhora R.F.
Ambootia T.G.
Springside T.G.
Kurseong
Ambootia Landslip
Scale
Metres 1000 600 200
1 2 3 Kms.

Fig. 3·20

Relative Relief

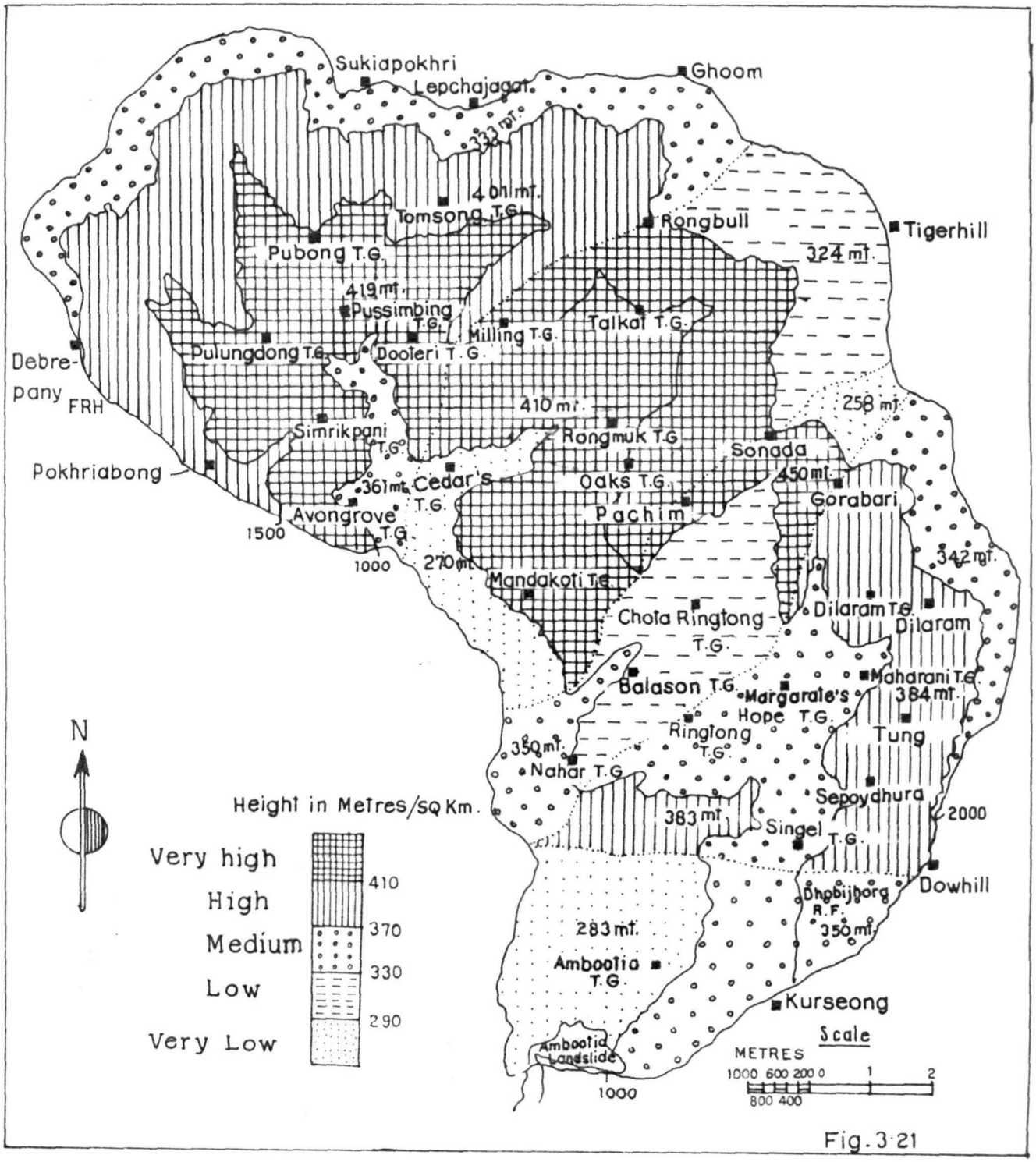


Fig. 3·21

middle and lower middle zones of Rongmuk , and upper middle zone of Pachim fall in very high relative relief category . The high relative relief category sprawls over upper middle zone of Upper Balason and upper middle and lower zones of Rinchintong . Distribution of other classes makes an haphazard pattern . In general, middle reaches of basins in northern half of the area are much steeper and hence more erodible than the southern ones .

3.11 SLOPE AND ITS DISTRIBUTION :

One of the geomorphological factor influencing the erosion is the sloping of ground surface . The greater the steepness greater is the velocity , carrying capacity , kinetic energy and erosivity of run off . In natural landscape , before the soils were used , water influenced the soil directly by erosion . Of the four eroding agents - water , wind , ice and gravity - the first is the most potent one and its erosivity is affected the most by the degree of slope (Smith et al , 1969) . An important parameter is the critical sloping which is the angle of inclination at which malignant erosion begins to occur on unprotected soil . Critical slope varies from 1.7 to 14 percent for surface , for 4 to 29 percent for slope gullies and 1.7 to 11 percent for valley gullies (Zachar , 1984) .

In the study area, one of the most conspicuous slope assemblages is that comprising a bare rock face followed by a substantial accumulation of talus . Development of

talus slope is an interesting phenomena . Weathering of rocks affects their shear strength , bulk density and permeability it penetrates rapidly when rocks are foliated , jointed or crushed (Gerrard , 1991) . From a equally exposed whole free face of rocks , within a unit time , a uniformly thick layer of rocks falls away due to weathering . This accumulates at the base as scree at the angle of repose of material . As the rock slope retreats , the talus slope extends upwards until it completely obliterates the free face . Such talus slopes with exposed rock faces are visible on eastern side of the study area .

As is seen (Fig 3.22) , very high degree of slope zone (more than 60 percent) occurs in and around Pubong , and Singel tea gardens besides a small patch in between Sonada and Gorabari . High degree of slope zone (50 to 60 percent) is most prominent in north western part and is met in Tomsong , Pubong , Pussimbing , Simrikpani and Avongrove tea gardens . Such areas are few in eastern side and are located in Talkat , Singel and Nahar tea gardens and Sonada - Gorabari stretch . Areas of very low degree slope (less than 30 percent) are met in and around Ghoom , Mahaldram and Dhobijhora reserve forest , in Margaret's Hope , Singel and Ambootia tea gardens . On an overview , medium degree slopes (40 - 50 percent) are most conspicuous in northern half and low degree slopes (30 - 40 percent) in the southern one.

On average slope map (Fig. 3.23) , it is seen that upper and lower middle zones of Upper Balason , upper middle zone of Pachim and lower zone of Rinchintong have more

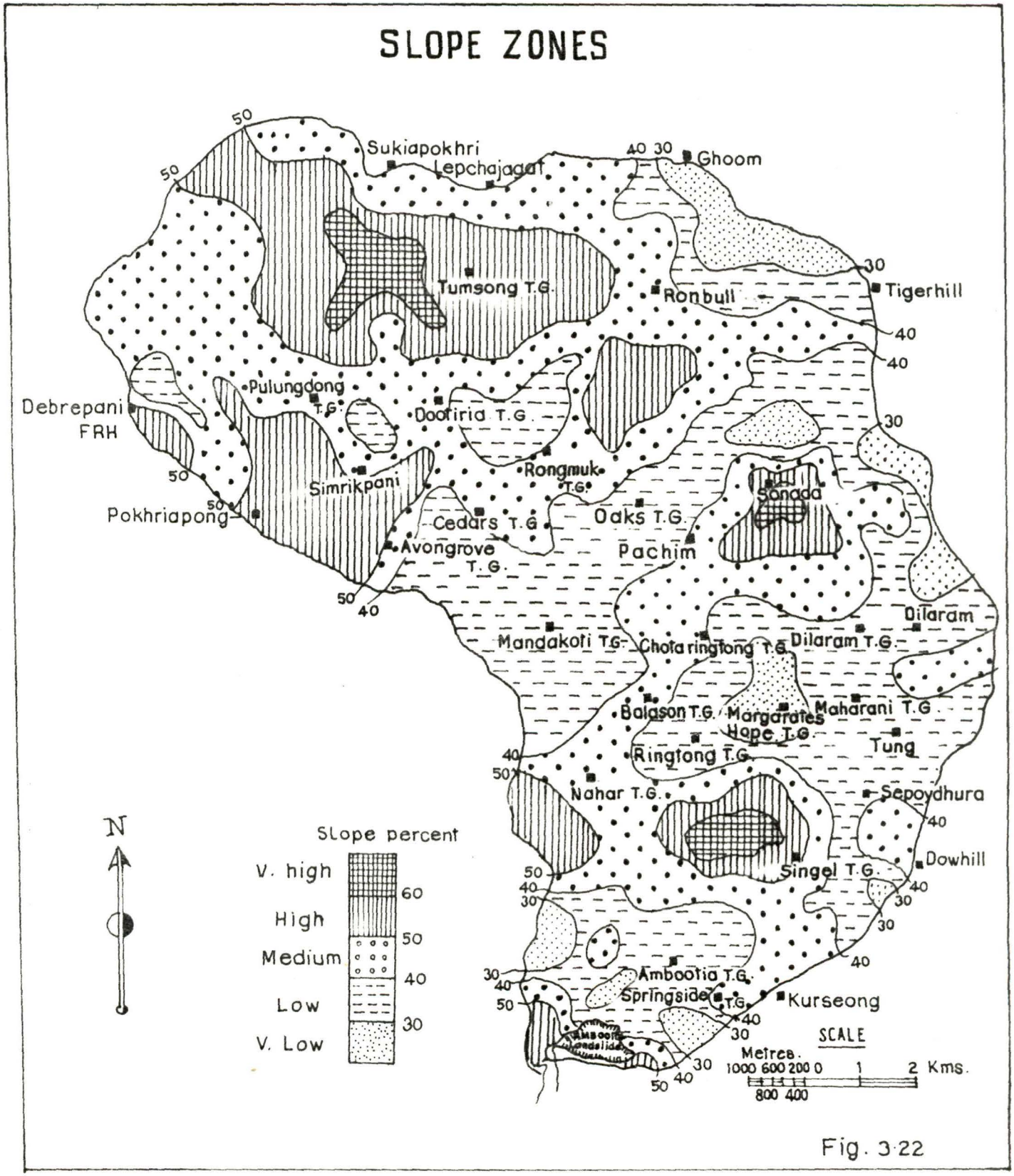

SLOPE ZONES
Sukiapokhri
Lepchajagat
Ghoom
Tumsong T.G.
Ronbull
Tigerhill
Pulungdong T.G.
Debrepani FRH
Dootiria T.G.
Rongmuk T.G.
Simrikpani
Pokhriapong
Cedars T.G.
Oaks T.G.
Sonada
Avongrove T.G.
Pachim
Dilaram
Mandakoti T.G.
Chota ringtong T.G.
Dilaram T.G.
Balason T.G.
Margarates Hope T.G.
Maharani T.G.
Tung
Ringtong T.G.
Nahar T.G.
Sepoydhura
Dowhill
Singel T.G.
Ambootia T.G.
Springside T.G.
Kurseong
N
Slope percent
V. high
High
Medium
Low
V. Low
60
50
40
30
SCALE
Metres.
1000 600 200 0 1 2 Kms.
800 400

Fig. 3.22

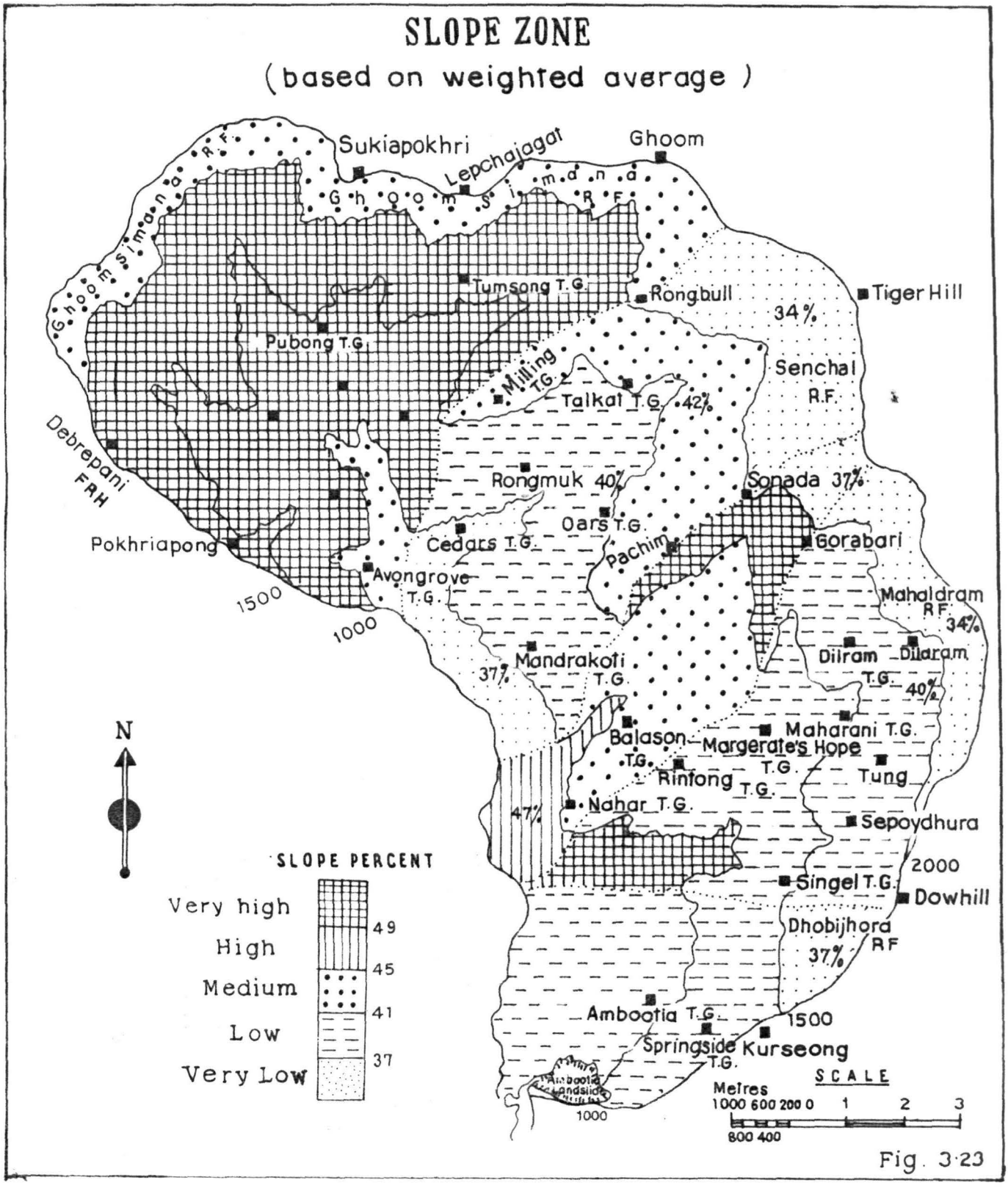

SLOPE ZONE
(based on weighted average)
Sukiapokhri
Lepchajagat
Ghoom
Ghoom Simana R.F.
Ghoom Sijmadna R.F.
Tumsong T.G.
Rongbull
Tiger Hill
34%
Pubong T.G.
Milling T.G.
Talkal T.G.
42%
Senchal R.F.
Debrepani FRH
Rongmuk 40%
Sonada 37%
Oars T.G.
Cedars T.G.
Pachim
Gorabari
Pokhriapong
Avongrove T.G.
1500
1000
Mahaldram R.F.
34%
Mandrakoti T.G.
37%
Dilram
Dilaram T.G.
40%
Maharani T.G.
Balason T.G.
Margerate's Hope T.G.
Rinfong T.G.
Tung
Nahar T.G.
47%
Sepoydhura
2000
Singel T.G.
Dowhill
Dhobijhora RF
37%
Ambootia T.G.
1500
Springside T.G.
Kurseong
Ambootia Landslide
1000
N
SLOPE PERCENT
Very high
High
Medium
Low
Very Low
49
45
41
37
SCALE
Metres
1000 600 200 0 1 2 3
800 400

Fig. 3·23

than 49 percent slope . Low and very low degree of slopes occupy major chunk of south and eastern part of the study area and sprawls over entire Ghatta - Hussain , entire Rinchintong except lower zone , upper Pachim , and upper Rongmuk zones . Besides lower middle and lower Rongmuk zones , too , fall in this category. The other classes are randomly distributed .

3.12 RUGGEDNESS :

The slope gives an idea about inclination of grounds but says little about degree of dissection which is best expressed by the ruggedness value . The ruggedness number represents an abstract idea and , roughly speaking , it represents surface area of terrain assuming it to have degraded from a horizontal cuboid with upper edge situated at the highest point of terrain and assuming further that no degradation except by the drainage lines took place and that interfluve points still exist at surface of so called cuboid . This concept is highly theoretical and no such situation can exist in nature . Nevertheless , it gives an indication of dissection of terrain.

As is seen Fig 3.24 , very high and high ruggedness is found close to Sonada , Gorabari , Mahaldram RF , Dilaram , Chota Ringtong , Mandakoti , Rongmuk , Talkat , Tomsong , Pubong and Avongrove tea gardens . Low and very low ruggedness is seen in major part of the area at random . Despite having higher

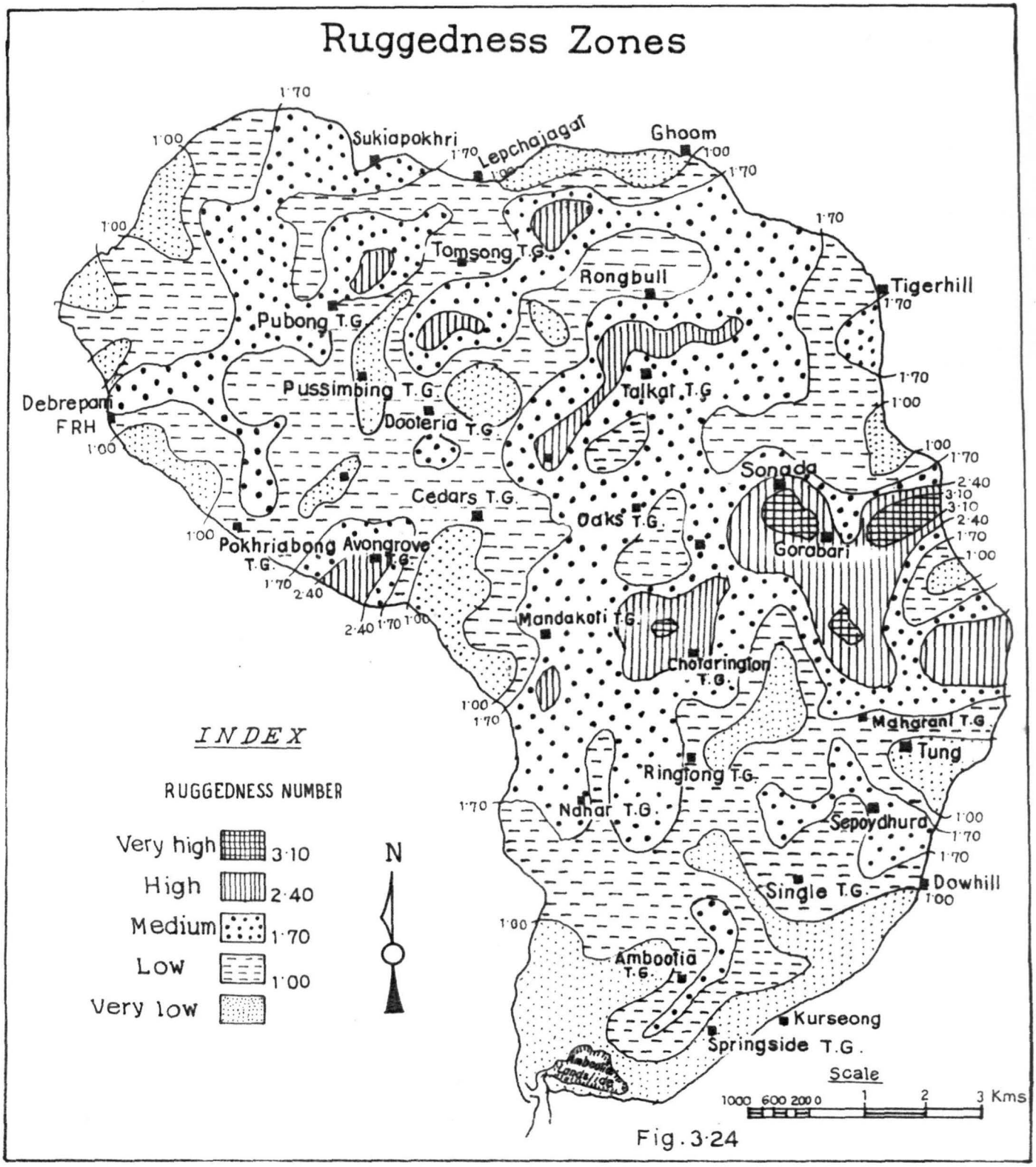

Ruggedness Zones
Sukiapokhri
Lepchajagat
Ghoom
Tomsong T.G.
Rongbull
Tigerhill
Pubong T.G.
Pussimbing T.G.
Talkat T.G.
Debrepani FRH
Dooleria T.G.
Sonada
Cedars T.G.
Oaks T.G.
Gorabari
Pokhriabong T.G.
Avongrove T.G.
Mandakoti T.G.
Chotarington T.G.
Maharani T.G.
Tung
Ringtong T.G.
Nahar T.G.
Sepoydhura
Single T.G.
Dowhill
Ambootia T.G.
Kurseong
Springside T.G.
INDEX
RUGGEDNESS NUMBER
Very high 3·10
High 2·40
Medium 1·70
Low 1·00
Very low
N
Scale
1000 600 200 0 1 2 3 Kms

Fig. 3·24

degree of slope (Fig 3.23) and higher relative relief (Fig 3.21) , the north western part of the study area has predominantly very low and low ruggedness . This is again indicative of high permeability leading to coarse drainage texture . The zones of basins , too , have been classified in respect of their ruggedness (Fig 3.25) . As is seen , upper middle and lower middle zones of Pachim have ruggedness number more than 2 , Rongmuk upper , upper middle , lower middle zones , and Rinchintong upper and upper middle zones have ruggedness numbers between 1.66 and 2.00 . Medium ruggedness in north western part is spectacular . In general , central and eastern parts of the basin are most rugged .

3.13 SEDIMENT LOAD , DISCHARGE AND VELOCITY OF JHORA FLOWS :

Ruggedness of terrain indicates the extent of surface area available for eroding agents to operate . The most important and direct evidence of erosion is obtained by sediment load in rivers , the discharge in it and the velocity of flowing water. Four rivers of study area , namely , Ghatta - Hussain , Rinchintong , Pachim and Rongmuk were monitored during July to November in the years 1992 and 1993 for assessing sediment load and discharge . The methodology adopted was not very sophisticated . The level of flowing water of all of them was measured with respect to bench marks fixed on bridges across them . Upper Balason could not be monitored due to absence of any easily approachable bridge

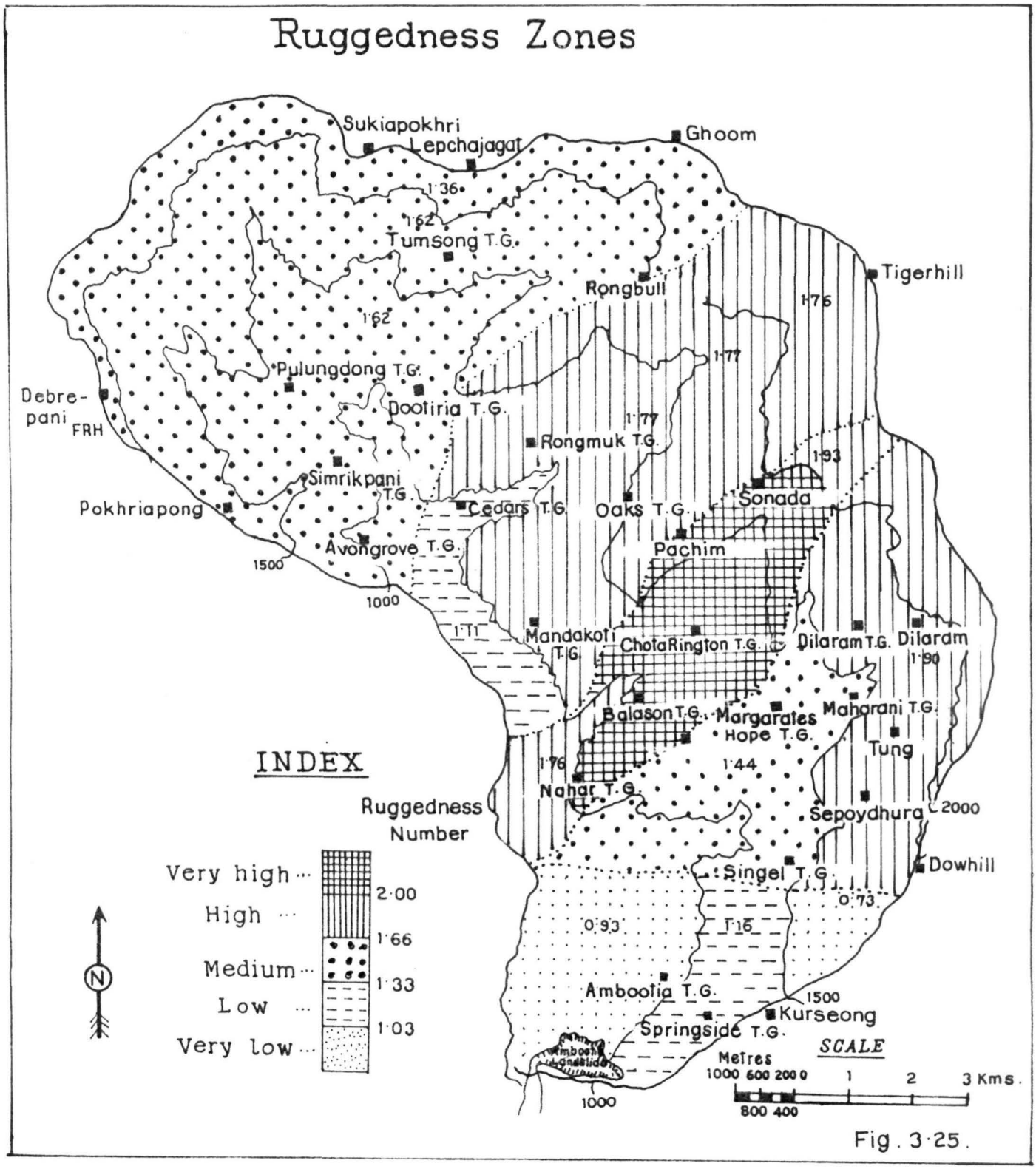

Ruggedness Zones
Sukiapokhri
Lepchajagat
Ghoom
1·36
1·62
Tumsong T.G.
Rongbull
Tigerhill
1·76
1·62
1·77
Pulungdong T.G.
Debre-pani FRH
Dootiria T.G.
1·77
Rongmuk T.G.
1·93
Simrikpani T.G.
Sonada
Pokhriapong
Cedars T.G.
Oaks T.G.
Avongrove T.G.
Pachim
1500
1000
1·11
Mandakoti T.G.
ChotaRington T.G.
Dilaram T.G.
Dilaram
1·90
Balason T.G.
Margarates Hope T.G.
Maharani T.G.
Tung
INDEX
1·76
1·44
Nahar T.G.
Ruggedness Number
Sepoydhura
2000
Very high
2·00
High
1·66
Medium
1·33
Low
1·03
Very low
Singel T.G.
Dowhill
0·73
0·93
1·16
Ambootia T.G.
1500
Kurseong
Springside T.G.
SCALE
Metres
1000 600 200 0
1
2
3 Kms.
800 400
1000
N

Fig. 3·25.

over it . During currency of rainstorms , attempt was made to measure water levels more frequently . Simultaneously water sample was collected and oven dry weight of sediment in it measured later on . Cross sections of rivers were obtained below the benchmark . Velocity of flowing water was assessed by float method at different levels of flows . The results have been tabulated in Appendices I to VIII .

Measurements of level of flows and collection of sediments could not be done during some parts of some months . In such cases results have been extrapolated for entire months for making realistic assessments . The soil loss per hectare of each basin area as extracted from Appendices I to VIII and is given in Table 3.20. This has also been shown graphically in Figure 3.26 .

As is seen from this , during the period July to November 1992 , Rinchintong and Pachim have produced 0.72 and 0.75 tons of sediment per ha . Soils in Ghatta - Hussain are getting eroded the least (0.57 tons / ha) and those in Rongmuk the most (3.05 tons / ha) . The month of August was most damaging and contributed 0.75 tons / ha out of a total soil loss of 1.27 tons / ha ; close to 60 percent of total during the period . October and November were the least erosive , as expected .

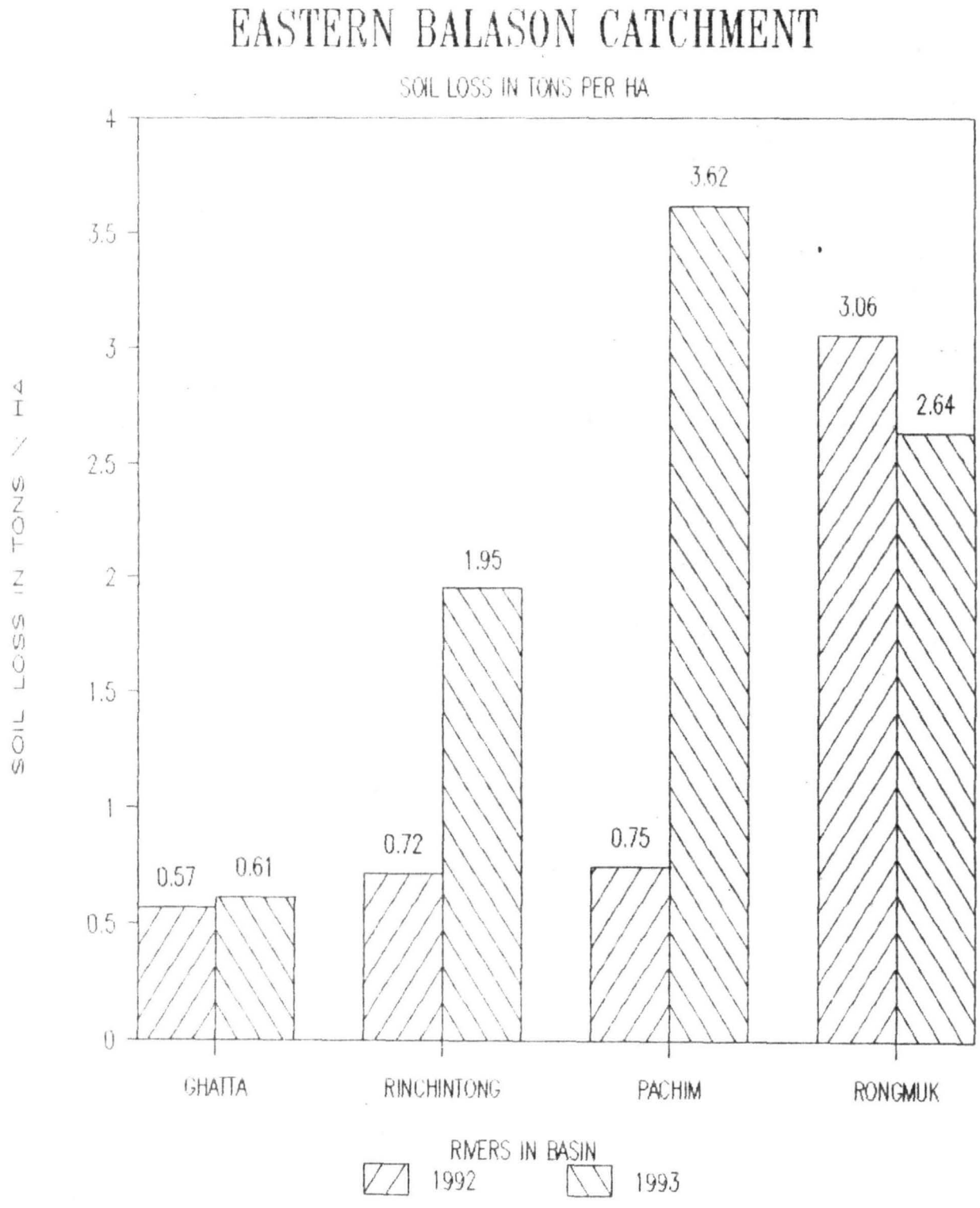

EASTERN BALASON CATCHMENT
SOIL LOSS IN TONS PER HA
SOIL LOSS IN TONS / HA
4
3.5
3
2.5
2
1.5
1
0.5
0
0.57
0.61
0.72
1.95
0.75
3.62
3.06
2.64
GHATTA
RINCHINTONG
PACHIM
RONGMUK
RIVERS IN BASIN
1992
1993

Fig. 3.26

TABLE 3.20

SOIL LOSS IN METRIC TONS PER HA

1992

RIVER	JULY	AUGUST	SEPT.	OCTO.	NOV.	TOTAL
GHATTA	0.18	0.18	0.19	0.02	0.00	0.57
RINCHINTONG	0.14	0.28	0.26	0.02	0.02	0.72
PACHIM	0.17	0.47	0.09	0.01	0.01	0.75
RONGMUK	0.61	2.09	0.29	0.05	0.02	3.06
AVERAGE	0.27	0.75	0.21	0.02	0.01	1.26

1993

GHATTA	0.21	0.19	0.19	0.02	0.00	0.61
RINCHINTONG	0.92	0.73	0.26	0.02	0.02	1.95
PACHIM	3.03	0.47	0.10	0.01	0.01	3.62
RONGMUK	1.68	0.60	0.29	0.05	0.02	2.64
AVERAGE	1.46	0.50	0.21	0.02	0.01	2.20

(Source : Author's own calculation)

During corresponding period of 1993 Ghatta - Hussain has produced the least , and Pachim the most , quantity of sediment per ha . Sudden spurt in rate of sediment production of Pachim , only the second lowest during 1992 in this regard , is explainable by collapse of Hill Cart road in between Gorabari and Sonada consequent upon a landslide down below the road bench . Unfortunately , data could not be collected during August and September 1993 (and figures of soil loss had to be assumed from corresponding periods of previous years) , which would have been quite revealing . Nevertheless , this shows that contribution of sediment load on account of other soil degradation processes is pea nuts in comparison to that by landslides , and bank failures . Rongmuk , here too , is seen as one of the highest contributors of sediments (2.64 tons / ha) . Overall soil loss from area was 2.20 tons / ha . Looking at Table 3.20 and Fig. 3.26 , it is not possible to locate any trend in regard to sediment production rate of different basins . The one contributing the least now , can be the highest producer later and vise - versa . It is because of the

fact that major chunk of sediments comes from landslides , bank failures , and quarries etc.

The rate of 0.75 tons per ha per year is compensation rate of erosion on the boundary between damaging and unharmful erosion (Zachar , 1984) . Most rivers in the eastern Balason basin are , therefore , either suffering from malignant erosion or are on the verge of it . Given the crude method adopted for assessment , non - inclusion of crucial months of May and June , and non - inclusion of bed load in compilation , the scenario of intensity of malignant erosion is far worse than what the data indicates . Besides the rate , the total soil loss , too ,throws some light on trends of soil erosion .

As is seen from from Fig 3.27 and Table 3.21 , total soil loss was much higher during 1993 than that in 1992 (4410.37 tons as against 3086.53 tons during 1992). Contribution of Rongmuk has always been the highest (2245.18 tons and 1938.31 tons during 1992 and 1993 , respectively) . Rongmuk has contributed over 72 percent of total soil loss in 1992 as against only 44 percent during 1993 .

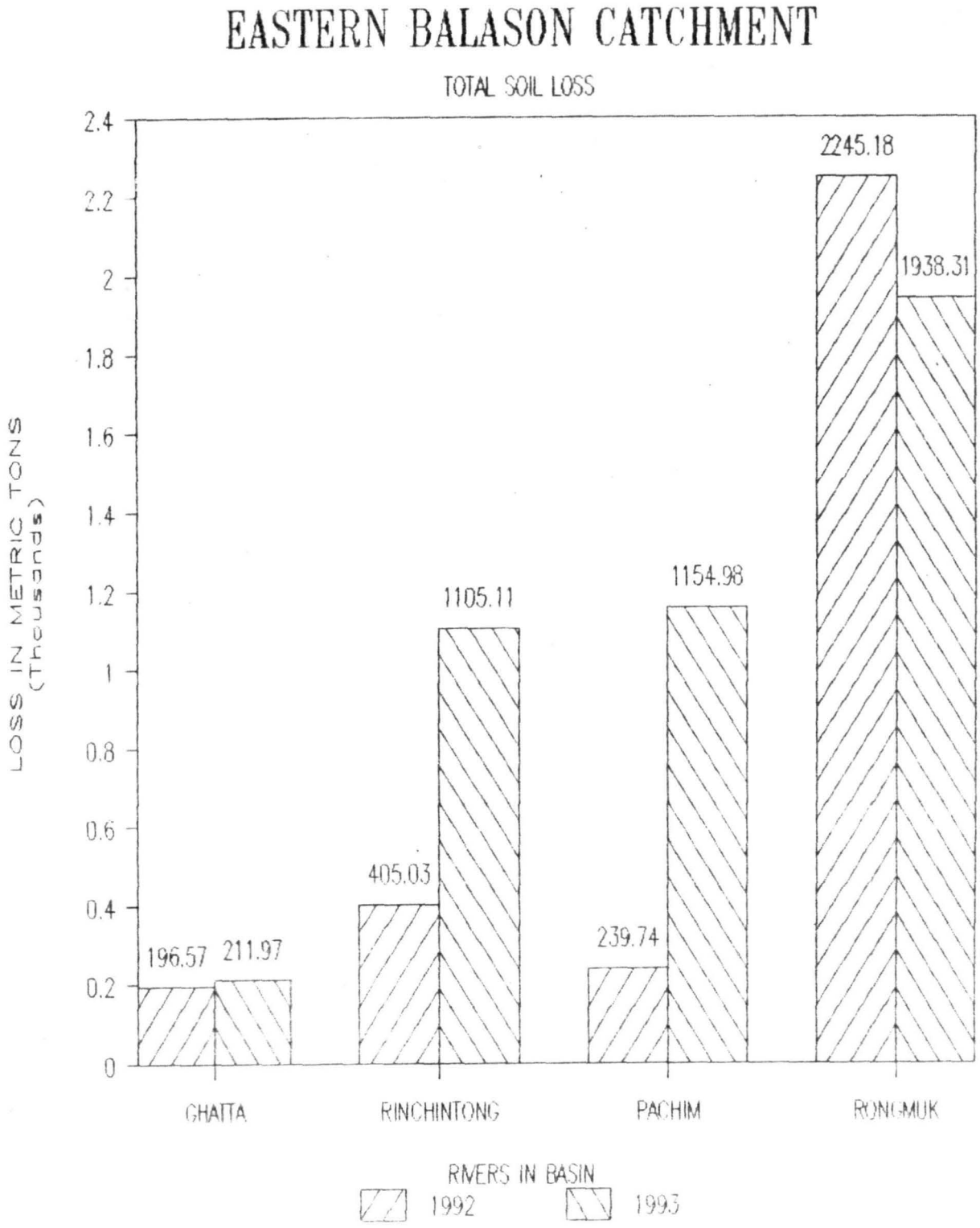

EASTERN BALASON CATCHMENT
TOTAL SOIL LOSS
LOSS IN METRIC TONS (Thousands)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
196.57
211.97
405.03
1105.11
239.74
1154.98
2245.18
1938.31
GHATTA
RINCHINTONG
PACHIM
RONGMUK
RIVERS IN BASIN
1992
1993

Fig. 3·27

TABLE 3.21

TOTAL SOIL LOSS FROM DIFFERENT BASINS IN METRIC TONS

1992

RIVER	JULY	AUGUST	SEPT	OCTO	NOV	AVERAGE
GHATTA	307.26	307.26	328.95	33.68	5.71	196.57
RINCHINTONG	385.41	789.16	746.01	54.48	50.10	405.03
PACHIM	273.97	746.73	151.13	13.44	13.44	239.74
RONGMUK	2240.29	7682.85	1070.42	170.00	62.32	2245.18
TOTAL	3206.94	9526.01	2296.51	271.61	131.57	3086.53

1993

GHATTA	368.46	323.03	328.95	33.68	5.71	211.97
RINCHINTONG	2601.86	2073.09	746.01	54.48	50.10	1105.11
PACHIM	4850.17	746.73	151.13	13.44	13.44	1154.98
RONGMUK	6187.89	2200.92	1070.42	170.00	62.32	1938.31
TOTAL	14008.39	5343.78	2296.51	271.61	131.57	4410.37

(Source : Author's own calculation)

While sediment discharge from Ghatta - Hussain was almost of similar level in both years that of Rongmuk had gone down during 1993 . The real contributors during 1993 had been Rinchintong and Pachim (273 and 482 percent over and above that of 1992) . Besides total soil loss discharge of rivers , too , throws some light on erosion characteristics of any basin.

Table 3.22 and Fig 3.28 show that in 1993 rate of discharge has registered a increase of 22 , 22 and 21 percent in Rinchintong , Pachim and Rongmuk rivers respectively whereas it has come down by 28 percent in Ghatta - Hussain . Due to lack of appropriate data , it is difficult to explain decline as rate of discharge depends on a number of factors including intensity of rainfall . It , however , does explain the concept of exponential growth of sediment load with slight increase of discharge . A increase of 22 percent in rate of discharge in Rinchintong and Pachim has increased total sediment load by 273 and 482 percent , respectively . The extent of

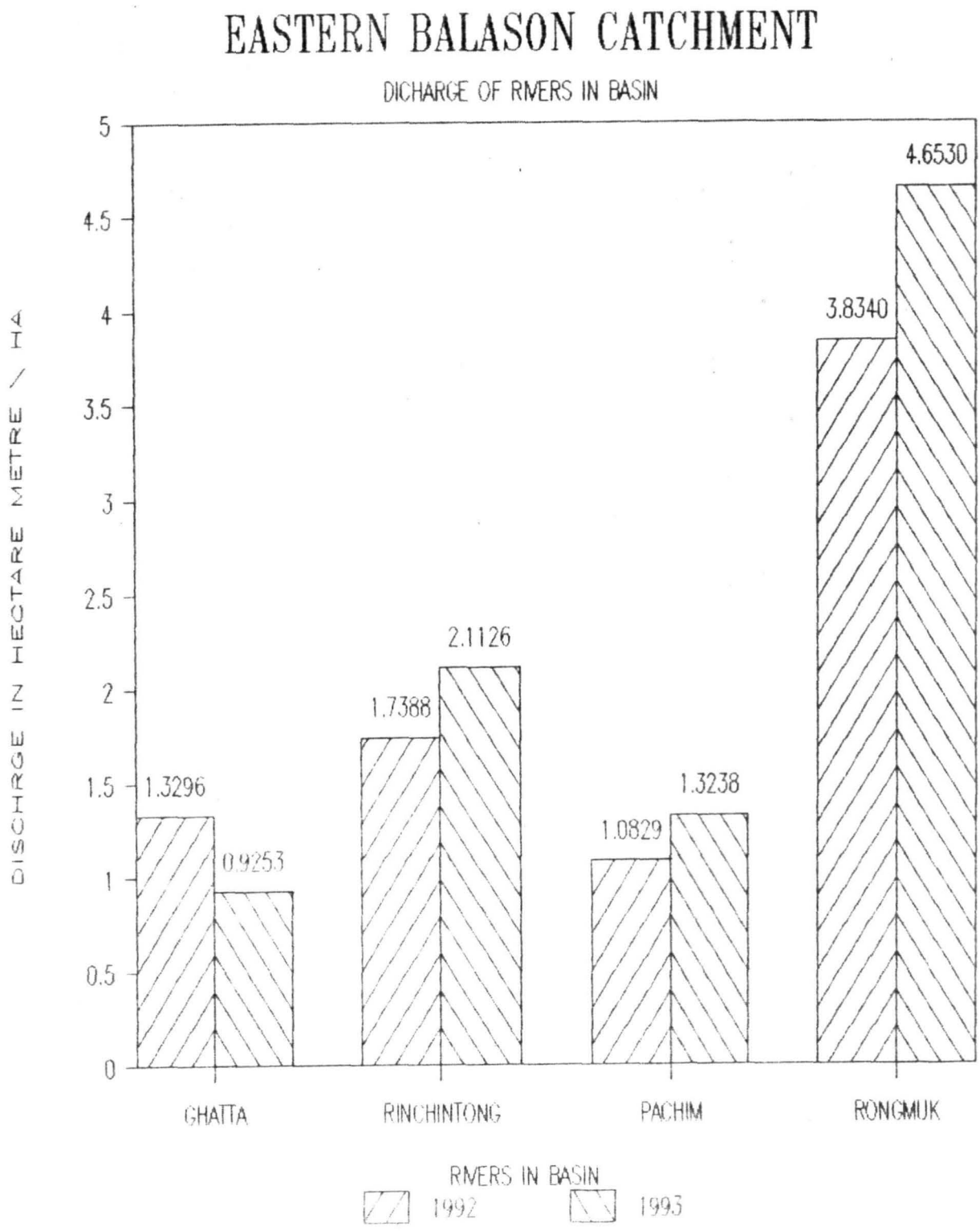

EASTERN BALASON CATCHMENT
DICHARGE OF RIVERS IN BASIN
DISCHRGE IN HECTARE METRE / HA
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1.3296
0.9253
1.7388
2.1126
1.0829
1.3238
3.8340
4.6530
GHATTA
RINCHINTONG
PACHIM
RONGMUK
RIVERS IN BASIN
1992
1993

Fig. 3.28

muddiness of water during monsoon is yet another parameter explaining erosion status of any basin .

TABLE 3.22

DISCHARGE OF RIVERS IN HECTARE METRE

RIVER	JULY	AUGUST	SEPT	OCTO	NOV	AV. HA.MT\HA
			1992			
GHATTA	831.09	831.09	359.39	220.83	51.17	1.3296
RINCHINTONG	1838.24	1390.15	944.40	522.02	217.22	1.7388
PACHIM	522.49	511.86	344.49	176.90	176.90	1.0829
RONGMUK	3887.60	2913.38	3312.84	1988.03	1988.03	3.8340
TOTAL	7079.42	5646.49	4961.12	2907.78	2433.31	2.3438
			1993			
GHATTA	402.88	455.26	390.92	220.21	126.92	0.9253
RINCHINTONG	1855.04	1705.82	1302.64	731.45	373.16	2.1126
PACHIM	697.25	511.86	344.49	282.20	282.20	1.3238
RONGMUK	5343.21	4466.61	3179.99	2636.04	1473.88	4.6530
TOTAL	8298.38	7139.55	5218.03	3869.90	2256.15	2.7259

Areas of Ghatta , Rinchintong , Pachim and Rongmuk are , respectively , 1725, 2825 , 1600 and 3675 ha.

(Source : Author's own calculation)

As is seen from Table 3.23 and Fig 3.29 , turbidity of waters of Ghatta , Rinchintong and Pachim had increased during 1993 by 39 , 79 and 247 percent over that of 1992 . The turbidity of Rongmuk has come down by 43 percent . The great enhancement of Pachim shows highly concentrated delivery of sediments as indicated earlier .

EASTERN BALASON CATCHMENT

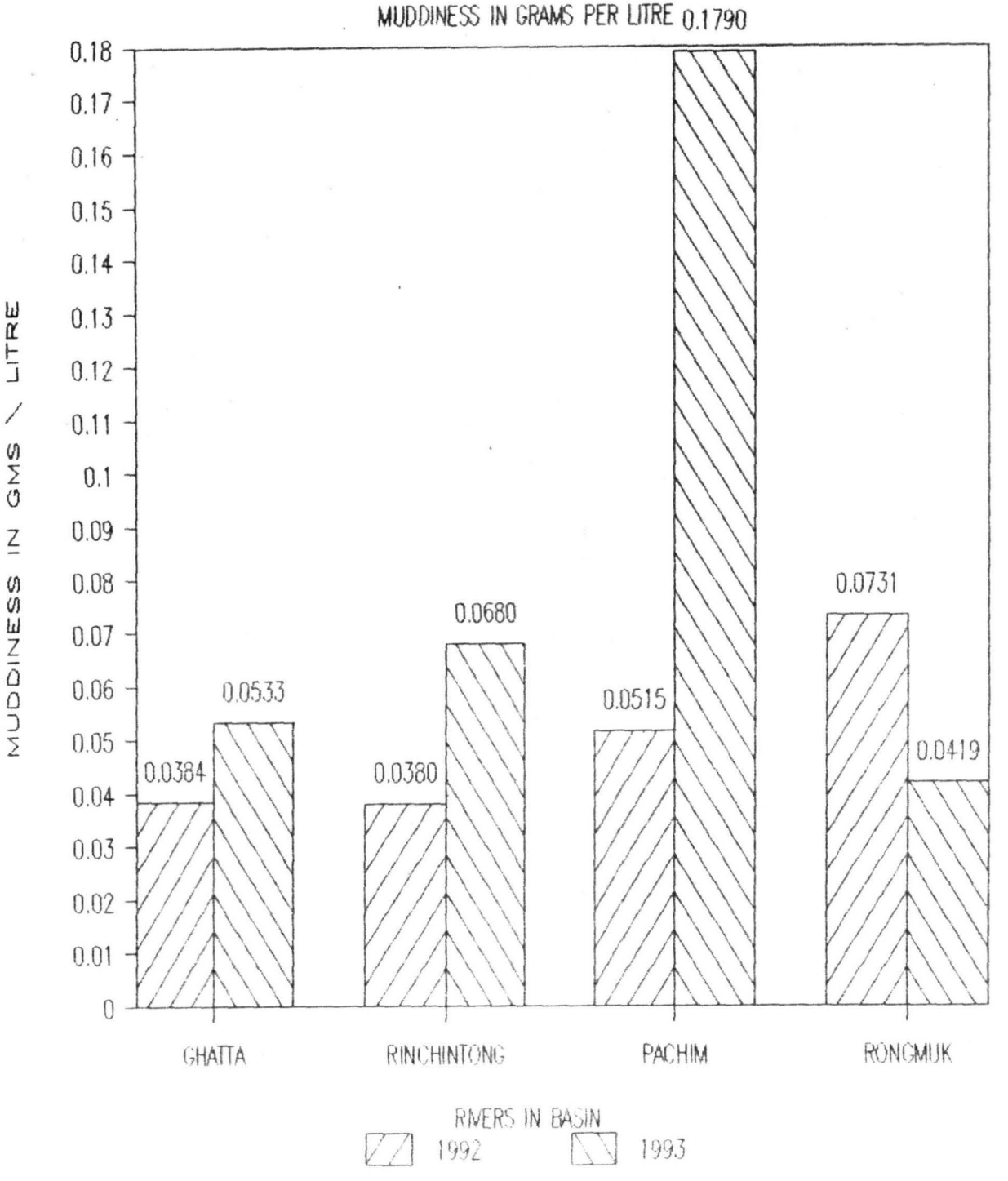


Fig. 3.29

TABLE 3.23

EXTENT OF MUDDINESS IN RIVER WATERS IN gm\litre

1992

RIVER	JULY	AUGUST	SEPT.	OCTO	NOV.	AVERAGE
GHATTA	0.0370	0.0370	0.0915	0.0153	0.0112	0.0384
RINCHINTONG	0.0210	0.0568	0.0790	0.0104	0.0231	0.0380
PACHIM	0.0524	0.1459	0.0439	0.0076	0.0076	0.0515
RONGMUK	0.0576	0.2637	0.0323	0.0086	0.0031	0.0731

1993

GHATTA	0.0915	0.0710	0.0841	0.0153	0.0045	0.0533
RINCHINTONG	0.1403	0.1215	0.0573	0.0074	0.0134	0.0680
PACHIM	0.6956	0.1459	0.0439	0.0048	0.0048	0.1790
RONGMUK	0.1158	0.0493	0.0337	0.0064	0.0042	0.0419

(Source : Author s own calculation)

CONCLUSION :

Thus , it is seen that rivers lying on southern side of the study area are steeper in their long profiles than those in northern side . The drainage density shows a mixed trend with high density areas located in central and central east part . The highest order of stream met within area is 6 and is met only in the lowest one fourth stretch of basin . Higher concentration of number of streams is seen in upper parts of southern half of the study area whereas the southern most tip shows the least value . Individual streams are lengthier as one goes from southern to northern side with few exceptions . Average length of streams show a variable trend but , in general , this value is smaller for first order streams in southern half of the study area . In one basin in central part they are exceptionally longer than others showing parallel drainage pattern . Bifurcation ratio of streams shows a mixed distribution and varies from 3.00 to 6.00 . Stream length ratio of rivers does not show any

particular pattern but , in general , streams located north ward in the study area have lower values for second and fourth order streams and higher values for others . In last 65 years , sinuosity of rivers have gone up , in general , with one showing a highly significant change . Another river has got its sinuosity reduced quite considerably . The study area is a labyrinth of ridges and valleys having multifarious land uses , the most extensive land use being tea gardens . Hypsometric distribution of area shows that two perched basins in central and northern parts still have to go considerable degradation to achieve maturity . Areas with high relative relief tend to concentrate on lower central part on northern half of study area with lower values for entire southern half . Areas with high degree of slopes are concentrated on north - western part with patches here and there in rest of the area . The ruggedness number shows a definite pattern of distribution with central and central eastern part showing the highest , the southern part the lowest and the north western part medium values . Analysis of sediment load and discharge of four rivers shows that rivers located on northern side are contributing maximum sediment load and discharge to river Balason . Analysis also shows dramatic increase in rate of sediment production per unit area and in turbidity of discharge indicating thereby concentrated delivery of soil into river by bank failures , landslides , quarries etc.

Various morphometric factors as described above , interact with pedological , climatic and biotic factors and have great bearing on ecological soundness of any basin

. For understanding the effect of this interaction on soil erosion status of any area , it is necessary to understand the mechanisms and processes of soil erosion . This is discussed in next chapter.