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DIFFERENT FREQUENCY OF THRESHOLD RAINFALLS TRANSFORMING THE MARGIN OF SIKKIMESE AND BHUTANESE HIMALAYAS

Abstract. Extreme heavy rains were observed at the margin of Bhutanese Himalaya from 1993 to 2000 and they were compared them with the effects of single continuous rain in Darjeeling Hills in October 1968. With help of satellite pictures and field reconnaissance it was possible to evaluate the role of clusterings. Every succeeding event passing the threshold values of slope and channel stability causes the acceleration of processes and extension of new erosional and depositional forms, which are finally reflected in the shape of alluvial fans at the mountain margin. Probably such clusterings play a substancial role in transformation trends of slopes and river valleys.

Key words: extreme rainfalls, clusterings of events, margin of Bhutanese Himalaya

INTRODUCTION

After 1950 and 1968 extreme rainfalls in the Darjeeling Himalaya (a marginal part of Sikkimese Himalaya) effects of catastrophic landslides and floodings were investigated (Dutt 1966; Nautiyal 1966; Starkel 1972a). During these continuous rains the rainfall totals fluctuated between 600 and 1,500 mm during 2–3 days and rain intensity at the end reached 1 mm · min^{-1} (Biswas and Bhadram 1984; Starkel 1972a). The recurrence interval varies between 20 and 50 years (Froehlich and Starkel 1995). During such event a total saturation of substratum is recorded followed by simultaneous transformation of slopes by mudflows, debris-flows and landslides. In the valley floors the aggradation processes are dominated over scouring. The alluvial fans are approaching upstream from the foreland into the hills (Starkel 1989; Froehlich and Starkel 1993). Of lower scale process was continuous rain of ca 500 mm in 3 days in July 1998 (max. daily exceeded 300 mm).

In between there were registered local heavy downpours. On 17.07.1988 near Kurseong was recorded upto 305 mm in several hours (Starkel and Basu 2000) creating local slips and debris flows.

During normal rainy seasons between extreme events, it follows a gradual recovery of soil covers and in the river channels the incision combined with removal of finer material. Only an apex section of alluvial fans at the mountain margin continuously rise up due to loss of water infiltrating in the sediments, causing an abrupt decline in the river discharge (Dutt 1966; Basu and Ghatowar 1986, 1990; Starkel et al. 1998).

The unique large Ambootia landslide valley, formed in October 1968 is still extending in the gradually minor scale due to specific hydrogeological conditions (Froehlich et al. 1992).

Allover monsoonal India there exist great diversity in the rainfall totals and frequency of extreme events (cf. Starkel 1972b). The highest rainfall totals and shortest recurrence intervals are also well known from Cherrapunji and Mawsynram (Singh 1996; Starkel et al. 2002). At the margin of Meghalaya Plateau similar sequencies of continuous extreme rains are recorded every year, even several times during one rainy season. It is reflected in a specific character of abrupt runoff and very reduced sediment load due to long time ago preceded degradation of available soil covers.

It arise a problem how slope area and fluvial systems respond to the changing frequency of extreme events. We know such examples from the other climatic zones. D. E. Burkham (1972) and later J. M. Hooke (1996) based on studies in the Gila river in Arizona recognized the extension of river channel cross-sections during several years with frequent floods, responding to every single event. Later during several dry years return to previous narrow channel were recorded. The role of flood clusterings in the turn of slope and channel evolution towards incision or aggradation were also documented in the Polish Flysch Carpathians (Ziętara 1968; Soja 1977; Starkel 1996).

The record of several heavy rainfalls and floods during one decade at the margin of Bhutanese Himalaya stimulated us to recognize the role of clustering with the recurrence interval of 2–3 years. The number of collected precipitation and hydrological records is relatively limited nevertheless the satellite images from 1996 and 1998 (taken heavy between floods) and field reconnaissance (especially in November 2000) gave the assumpt to present the concept on the geomorphic role of clustering effect of threshold rainfalls.

RELIEF OF THE FRONT OF BHUTANESE HIMALAYA

The course of the Himalaya margin among the Tista, Jaldhaka, Torsa and Jainti river valleys, at 80 km length is very distinct although not straight. The hills are rising suddenly above the alluvial plains and fans from 300 to 600–700 m a.s.l. at 1–2 km distance and at the most sections upto 1,200–1,500 m a.s.l. at 3–5 km distance. Slopes are steep 20–40°. The mountain front is heavy dissected by river valleys of various size, smaller ones are at 0.5–2 km distance, larger valleys every 5–10 km. The mountain front is controlled by two overthrust tectonic lines (Pawde and Saha 1982). The inner Main Boundary Fault separates Siwalik nappe from the central part built of several overthrusted metamorphic units of Daling Buxa and Gondwana series at its margin, composed of sandstones, slates, quarzites with intercalations of dolomites, limestones and coal beds. The external Himalaya Front Tectonic Line separates Siwaliks from the foredeep, only in some sections is expressed by the mountain margin, at many others being subsided, is either visible as a shelf of higher terraces rising over floodplains (between Chel and Jaldhaka — cf. Nakata 1972) or fully burried under rising fans of the Gish or Chel rivers.

The extensive foredeep plain is sloping down from about 200–300 m a.s.l. upto the Brahmaputra river. Its marginal belt 5–10 km wide built of coarse gravels is composed of alluvial fan apexes of large rivers (upto 1,000–4,000 km^2 catchment area) or medium fans of tributaries frequently below 100 km^2 catchment and small steep fans formed at outlets of gullies and debris flows. The gradient of this belt fluctuate between 4–6‰ and may pass 10–20‰.

The second reach 5(10)–20 km distance from the mountain margin has a mean gradient 2–3‰ and is occupied by fans of larger rivers, separated by platforms of higher terraces. In this zone appears dense network of tributaries supplied by springs from groundwaters, their channels are overflooded during heavy rains, which also extend over the plains. At 20–30 km distance or more the gradient goes down from 2‰ to 1‰ or less — it presents the belt of frequent avulsions and bifurcations, built mainly of sandy bars and overbank deposits, the channels change from braided to meandering.

RAINFALL DISTRIBUTION IN RELATION TO DISTANCE FROM THE MOUNTAIN MARGIN

In all studies regarding landslides and floods in the Darjeeling Hills (cf. Starkel and Basu 2000) our attention was concentrated on the rainfall distribution inside of the Hills depending on elevation, slope exposure and distance from the margin. Less attention was paid to the plains. On the east side of the Tista valley, rainfall stations frequently are located in the plains and only a few on the margin of hills.

Nevertheless the picture is very interesting (Fig.1). In the plains at 30–40 km from the margin the mean annual rainfall for the period 1901–1950 fluctuates between 2,000 and 3,500 mm, closer to the mountains grows to 4,000 mm and higher. Makrapara Tea Garden located at the base of the mountain front, records 5,800 mm (mean value during the last decade). Two stations in the frontal hills record 5,323 mm (Buxa Duar 850 m a.s.l.) and 6,750 mm (Mission Hill 400 m a.s.l. — mean value during 8 years).

These records indicate that the mountain margin of Bhutanese Himalaya gets more rain then areas at similar elevations in the Darjeeling Hills, but also the rainfall totals in the plains are much higher here. This is an effect of position

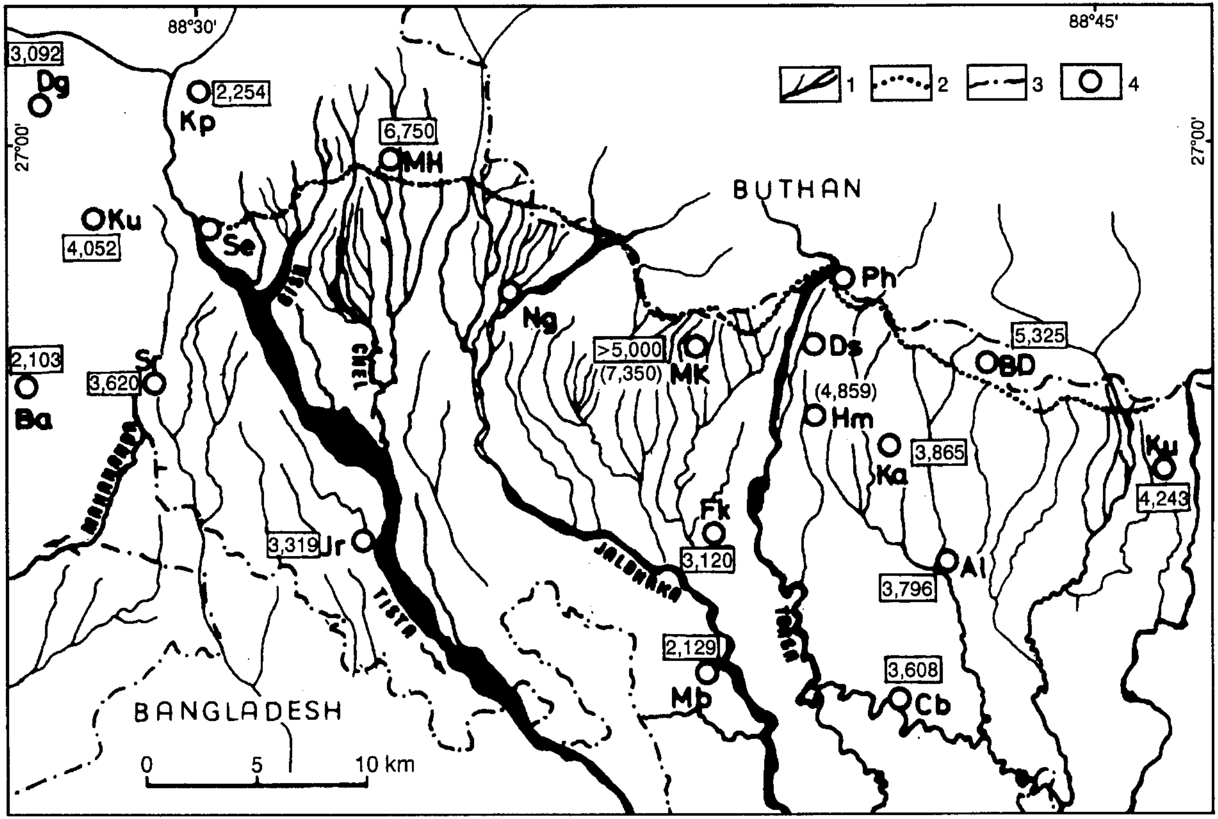

Fig. 1. Mean annual rainfalls at the margin and foreland of the Bhutanese and Sikkimese Himalaya. In brackets total rainfall during particular year. 1 — rivers, 2 — margin of Himalaya, 3 — state boundaries, 4 — raingauge stations: Dg — Darjeeling, Ku — Kurseong, Kp — Kalimpong, Se — Sevoke Bridge, Sr — Siliguri, Ba — Bagdogra, Jr — Jalpaiguri, MH — Mission Hill, Ng — Nagrakata, Mk — Makrapara, Fk — Falakata, Mb — Mathabhanga, Ph — Phuntsholing, Ds — Dalsingpara, Hm — Hasimara, Ka — Kalehim, Al — Alipure Duar, Cb — Cooch Bihar, BD — Buxa Duar, Ku — Kumargrane

of frontal line during the summer monsoon, which very frequently do not enter in the mountains (Biswas and Bhadram 1984; Das 1987). The deviation of the mean annual rainfalls may reach ±1,500 mm (Makrapara recorded from 3,750 upto 7,350 mm).

HYDROLOGICAL REGIME

The fluctuations of the river discharge are very frequent eastside of the Tista river upto the total drying up of smaller creeks in winter period as the Lish and Gish. G. N. Dutt (1966) in his paper has mentioned following records from 1952 (Table 1).

Table 1

River discharges in 1952

River	Area $[km^2]$	Max Q $[m^3 \cdot sec^{-1}]$	Min. Q $[m^3 \cdot sec^{-1}]$	Spec. $[m^3 \cdot km^{-2}]$
Lish	49.2	254.7	0.25	5.18
Gish	160.6	630.2	0.08	3.42
Chel	103.6	184.5	0.06	1.18

The highest discharge of large rivers is also characterized by very high specific runoff exceeding frequently $3m^3 \cdot sec^{-1} \cdot km^{-2}$. This is an effect of deep penetration of humid air masses into the mountains. That situation was observed in October 1968, when humid masses moved up to Southern Sikkim (cf. Starkel and Basu 2000, Table 2).

Table 2

Highest discharges of selected rivers

River (station)	Area $[km^2]$	Max Q $[m^3 \cdot sec^{-1}]$	Spec. $[m^3 \cdot km^{-2}]$
Tista (Coronation Bridge)	7,612	17.45	2.29
Jaldhaka	2,616	8.85	3.38
Torsa (Phuntsholing)	4,045	12.23	3.02

Each rainy season is characterized by at least several rises and decreases of the water level, which normally does not exceed 2–4 meters and by transformation of braided channel pattern with shoals and bars (Sarkar 1997; Starkel et al. 1998; Starkel and Basu 2000).

These floods carrying high bedload cause the rising of river beds up to 1–3 meters in 10–18 years and even to 0.5 m during one flood (*Preparation...*

2001) as well as the extension of belt with channel bars by 50% in the period 1930–1990 (Lish river cf. Basu and Ghatowar 1986). In case of the Lish and Gish rivers this is also an effect of intensive mining activities.

THRESHOLD RAINFALLS AT THE MARGIN OF BHUTANESE HIMALAYA IN THE PERIOD 1993–2000

During the period 1993–2000 there were recorded three extreme rainfalls in July 1993, 1996 and 1998 in the catchments of the Jaldhaka, Torsa and Jainti rivers. The second one of them was extended even upto the Tista valley (Fig. 2, Table 3).

Table 3

Daily and total rainfall in mm during three extreme continuous rains at the margin of Bhutanese Himalaya in 1993, 1996 and 1998

Raingauge station	19.07.1993	20.07.1993	21.07.1993	19–21.07.1993
Makrapara	280	488	838	1,606
Dalsingpara	123	330	387	840
Hasimara	220	368	791	1,379

Raingauge station	11.07.1996	12.07.1996	13.07.1996	14.07.1996	11–14.07.1996
Sevok Bridge	111	309	404	82	906
Jalpaiguri	47	94	124	224	489
Nagrakata	82	70	208	86	446
Dalsingpara	75	172	262	150	659
Hasimara	66	185	267	195	715
Phuntsholing	151	137	431	74	793

Raingauge station	20.07.1998	21.07.1998	22.07.1998	23.07.1998	24.07.1998	20–24.07.1998
Sevok Bridge	36	61	32	27	78	234
Nagrakata	+	+	217	98	+	
Makrapara		149.8	140.8	147.2	138.7	576
Dalsingpara	216	84	98	137	153	688
Hasimara		+	85	110	+	

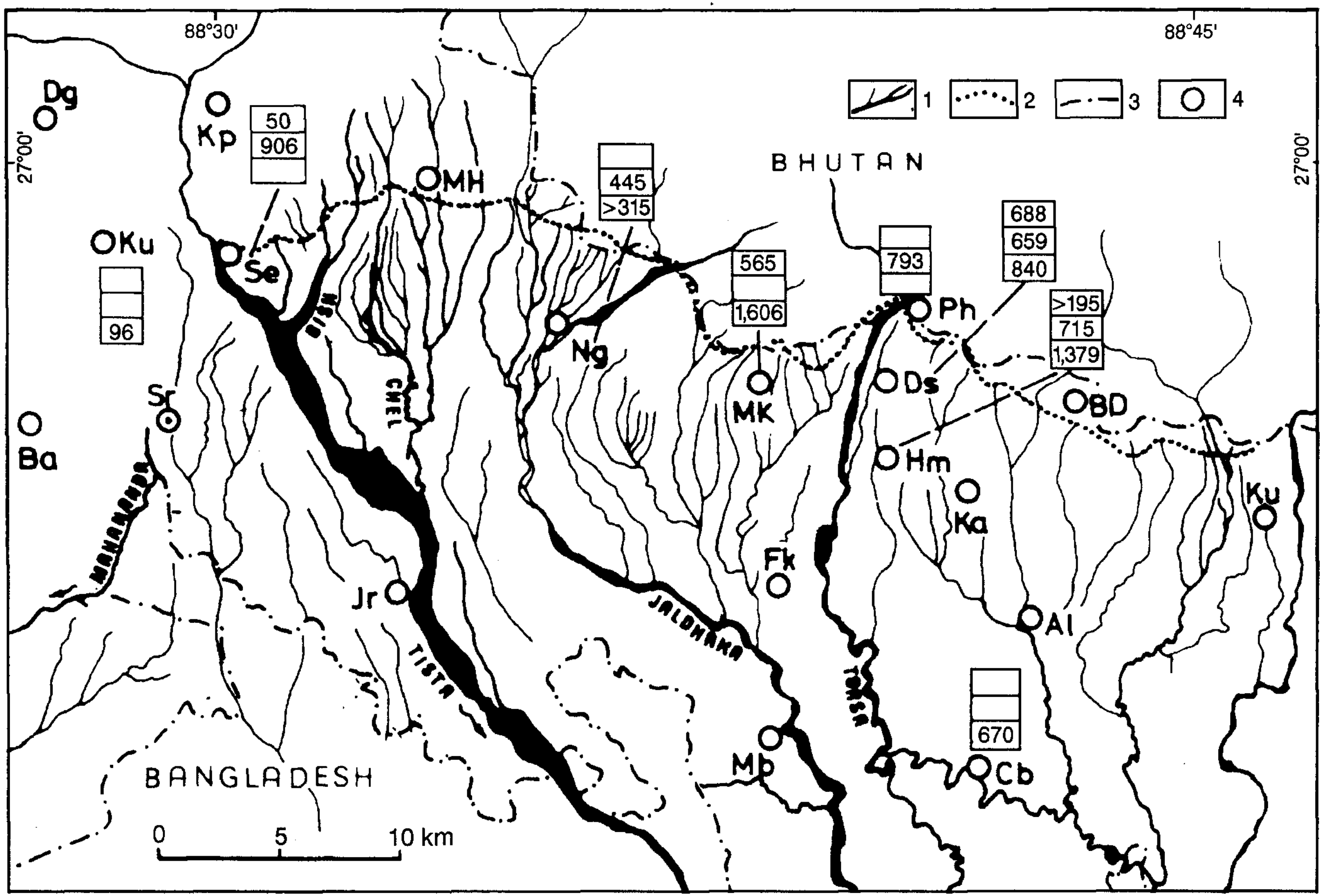

Fig. 2. Total rainfalls during extreme events in July 1993, 1996 and 1998 (compare Table 3). Explanation of signatures and abbreviations, see Fig. 1

The first threshold event from 19 to 21 July 1993 was characterized by rainfall totals which probably never were recorded at the margin of Sikkimese and Bhutanese Himalaya. The Makrapara Tea Garden located at 1 km distance from the hills registered 1,606 mm with the highest precipitation of 838 mm during the last day. At Hasimara, 10 km from the hill margin, it was recorded 1,379 mm. It is probable that the rainfall on the mountain front was even higher.

Between that continuos rain and the next threshold event in July 1996 there were several heavy rains measured at Dalsingpara, mainly in 1995, with the highest diurnal rain of 241 mm (Table 4).

Table 4

Other extreme rainfalls between the events in 1993, 1996, 1998 and our visit in November 2000 at Dalsingpara T.E.

Data	Extreme rainfalls	Max daily rainfalls
19–21.07.1993	840	387
14–16.06.1995	361	241
5–9.07.1995	358	105
14.08.1995	173	
3–4.07.1996	369	187.5
11–14.07.1996	659	262.5
8–9.06.1997	185	148
6–8.07.1997	255	109
1.08.1997	171	
8.09.1997	148	
8–13.06.1998	915	200
16–18.06.1998	409	225
2.07.1998	445	
20–24.07.1998	688	153
17.08.1998	217	
26.08.1998	262	
9.07.1999	245	
18–20.08.1999	327	164.5
23–25.08.1999	438	245.5
19–20.06.2000	414	230.5
4–5.07.2000	258	141
1–4.08.2000	501	237.5

From 11 to 14 July 1996 it was recorded only 450 to 900 mm, with the highest daily rainfall passing 400 mm at several localities. It was observed a distinct rise of totals closely to the mountain front (Fig. 2).

Between 14 July 1996 and 20–24 July 1998 were registered several continuous rains and heavy downpours among them in June–July 1998, series of 6 and 3 days long with rainfall totals respectively 915 mm and 409 mm and then daily rain of 445 mm (at Dalsingpara Tea Estate — Table 4). The main event of 20–24 July proceeded that sequence and was characterized by rainfall totals which do not pass 700 (with daily highest rainfalls 150–200 mm, Table 3).

Before satellite survey in December 1998 there were still two heavy rains above 200 mm in August 1998, which could cause farther extension of landslides and aggradation in the valley floors.

Our inspection in November 2000 was preceded by at least two continuous rains in 1999 (each of 300–450 mm order) and the next three in summer 2000. The last one 1–4 August with rainfall totals above 500 mm and diurnal rain of 237.5 mm probably left fresh debris flow features along the Torsa river near Phuntsholing.

THE EFFECTS OF CLUSTERING OF EXTREME EVENTS

The effects of clusterings of extreme rainfalls from 1993 to 2000 at the margin of Bhutanese Himalayas were examined as a total (summarizing) effect based on the satellite images and inspection in November 2000. We tried also to evaluate the role of separate events.

The second author of this paper visited studied area between succeeding of events. The first author during the flights to Gauhati in January 1996 and in next years observed high number of landslides and extensive aggradation in the valley floors just in this belt east of Tista, similar to that surveyed by him after October 1968 in Darjeeling Hills. The distinction between the effects of threshold rainfalls in 1996 and 1998 was possible studying the satellite images taken either in November 1996 or in December 1998. Fortunately two pictures were partly superimposed, we got for the longitudinal belt 6 km wide the possibility to compare the role of earlier events and next 1998 event (Fig. 3, Photo 1). In November 1999 we observed the Lish and Gish river valleys with the progressing aggradation in the braided river channels. In November 2000 during 2-days trip, together with W. Froehlich from Poland, we visited these heavily damaged areas along the Pagli and Torsa rivers upto Phuntsholing at the Bhutanese border, as well as Buxa Hill Reserved Forest upto the Jainti river.

About the role of heaviest rainfall in July 1993 we know only that many new features on the slopes as well new channel pattern of braided Torsa, Jaldhaka and other rivers were formed.

Fig. 3. Comparison of two satellite images of the Himalaya margin in the catchment of Pagli and Titi river made on December 1996 and November 1998. 1 — landslides and braided channels visible on image from 1996, 2 — extension of landslides and braided channels in 1998

All the hill margin near Surti T.G. the gully about 2 km long was transformed by deep landslide and its debris flow tongue spread over the plain forming 1 km long debris fan (similar feature to the Ambootia landslide valley — Froehlich et al. 1992).

The total effects of two extreme events were registered on satellite pictures from 31 December 1996. On that picture covering the area between Jaldhaka

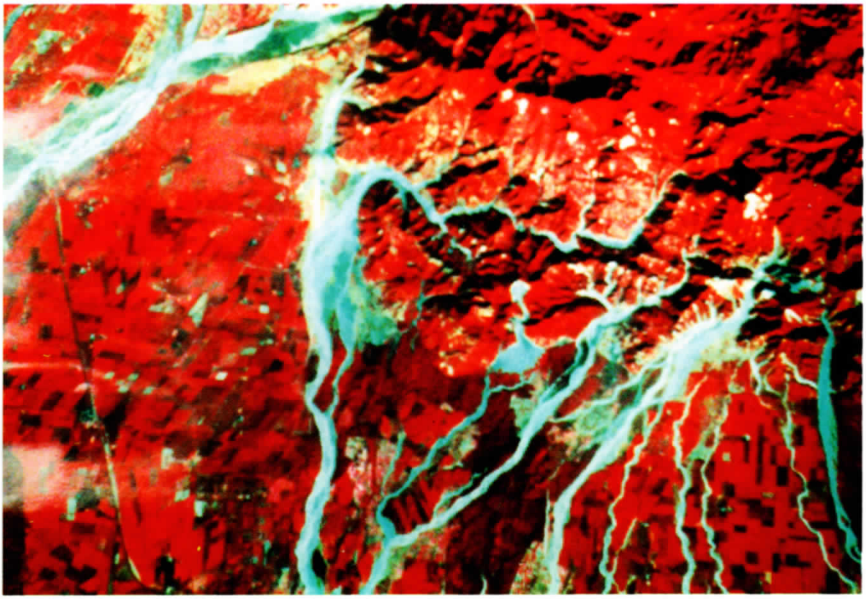

Photo 1. Satellite image of the margin of Bhutanese Himalaya in the Rehti, Pagli and Titi river catchments showing hundreds of landslides and extended braided channels (taken in December 1996). In the middle visible landslide valley with extensive torrential fan near Surti T.G.

Photo 2. Landslips and debris flows dissecting the mountain margin and fans building up the braided channel of the Pagli river (November 2000)

Photo 3. Extensive alluvial fan with several branches of the Pagli river near Makrapara T.G. (November 2000)

Photo 4. Mostly dry channel of the Jainti river with extensive torrential fan of the left tributary transformed by landslide and debris flow (November 2000)

and Torsa river valleys were visible hundreds of landslides concentrated in the marginal part of the hills, usually disconnected with the valley floors excluding large landslide at Surti T.G. Extensive zones of aggradation 1–2 km wide in the apex zone (expanding in the hilly reaches) declines rapidly downstream spreading in case of the Pagli river into 4–5 branches of different width over the alluvial fan. The appearance of fresh sandy bars along the river channels, which to the south start over the extensive fan surfaces, confirm the formation of flood waves in these shallow channels fed by heavy rains falling also in the plains (Photo 1).

The next satellite image taken on 13th November 1998 shown the area between the upper Pagli and Torsa valleys upto the margin of Buxa Hill reserve. In the hills there are many landslide areas, the larger ones of 1 km^2 size are mainly connected by fans (or debris flows?) with the alluviations in the main valleys.

Very characteristic features are the fingerlike landslides in the hilly valley heads. To the south over the shelve of higher terrace the dense network of V-shaped valleys was transformed into flat depositional bottoms ending with fans building up the floodplain of the Torsa river. The braided channel and the most of Torsa floodplain was covered by fresh sediments upto 2.5 km width. The topographic map from 1930 also shows the braided pattern, but the belt of bars was that time only to 1 km wide (Fig. 4).

The comparison of two satellite images from December 1996 and November 1998 shows very characteristic changes (Fig. 3). Many landslides present in 1996 after two years were extended and new ones were created. The largest ones were now united with the main valley floor of the Pagli river (Photo 2). During the visit in November 2000 at that place it was stated that the unifying was realized by a simultaneous retreat of niches, extension of debris flows down valley and by rising of torrential fans growing up-valley from the Pagli river floodplain (Photo 3). The former V-shaped small valleys dissecting the frontal zone of the hills were replaced by flat-bottom valley with steep gradient exceeding 10–20‰ (cf. Froehlich and Starkel 1993, and Fig. 5). The channel plain of the larger river Titi (at fig. 3 on the right) 0.5–0.8 km wide, extend after 1998 event about 10–25%. This is connected with lateral erosion and supplying of river system by colluvia from large landslide in the upper course.

The observations made during our visit in November 2000 showed very fresh depositional features over most of floodplains, debris flows in the tributaries and landslides in valley heads. This is probably the effect of reactivation of these forms and heavy bedload during less distinct events in summer 2000. Of this character is the reactivation of landslide valley and debris flow which damaged a part of Phuntsholing town at Bhutanese border. Also the aggradation in the densely forested Buxa Duar Forest Reserve is a proof of very high rainfall totals and intensity during last years. In deep and narrow V-shape valleys over

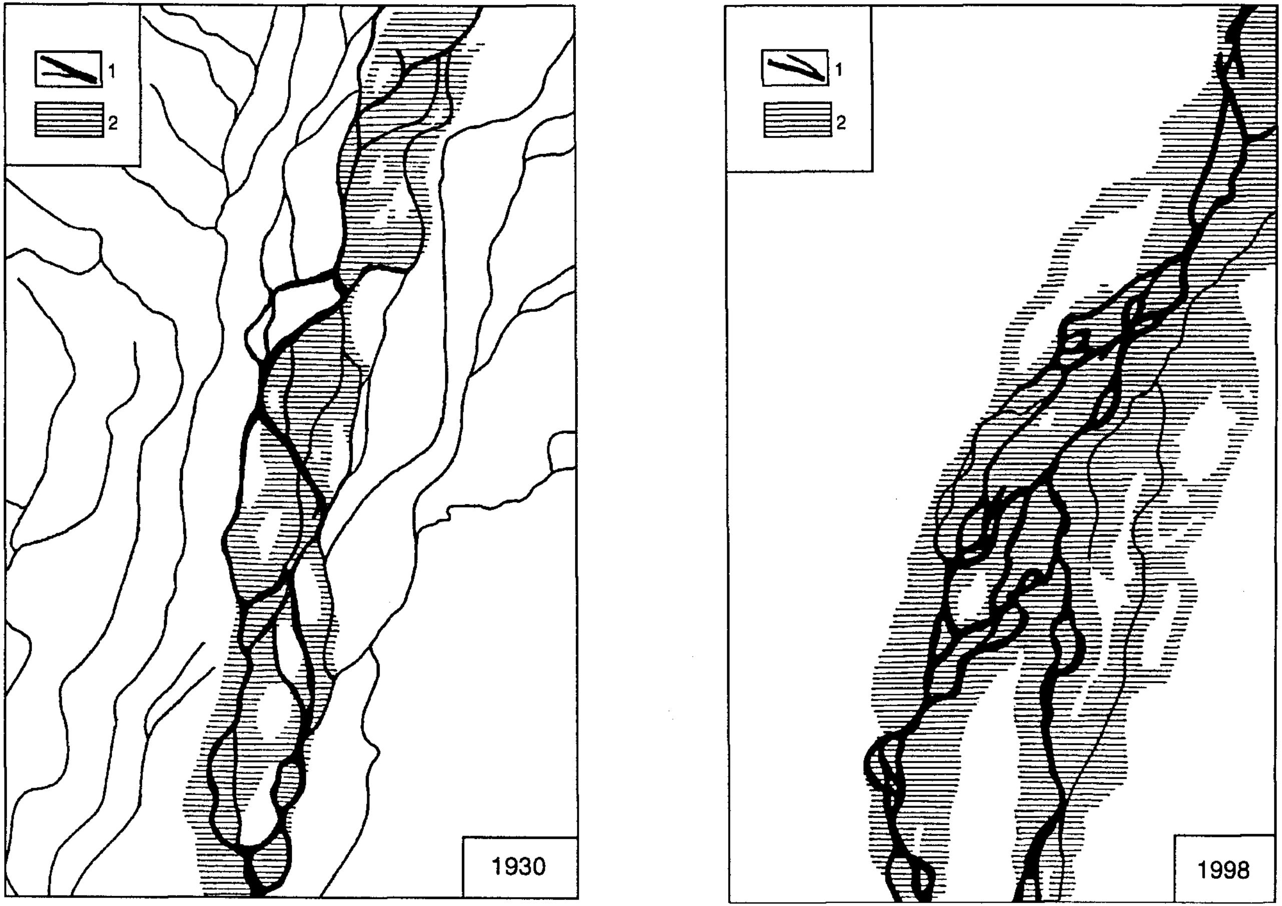

Fig. 4. The extend of braided channel of Torsa river in 1930 (after topographic map) and in 1998 (based on satellite image)

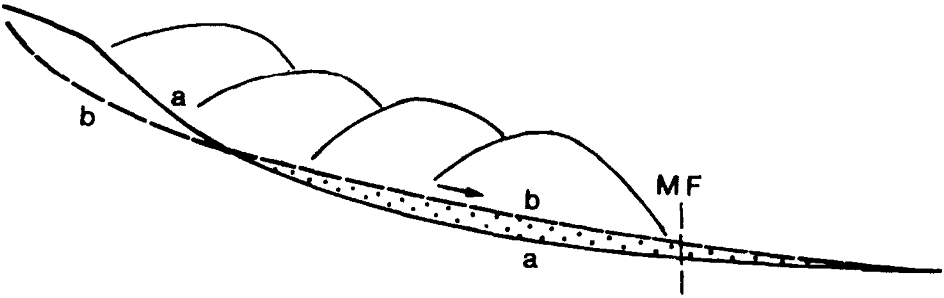

Fig. 5. Schematic longitudinal profile of small valley dissecting the margin of Bhutanese Himalaya before (a) and after (b) the clusterings of extreme events

the bedrock there are the remains of debris flows with blocks 2 meters and more in diameter. Over the fan of small dry creek Bala we observed not only fresh deposits in the channel, but also the deposition of gravely crevasse sprays over the forested 2–3 m higher fan plain.

In the Jainti river valley the channel floor 200–300 m wide is built of coarse gravels with boulders upto 20–50 cm, which now come out on the forested terrace plain (Photo 4). The bridge across the river was damaged twice by floods in 1993 and 1996. The measurements of rising up of channel floor have shown the aggradation of 3 meters between 1993 and 2000. In the valley head of a left tributary about 3.5 m long, probably in 1998 was formed, a deep landslide, transformed downslope into debris flow, which burried many trees (Photo 4). The fresh flat surface of debris flow, with network of episodic channels and bars indicates that the transport of material was continuing in summer 2000 (cf. Table 4), the landslide scarp was retreating and the front of torrential fan extending.

The total effect of clustering of extreme events is very spectacular. Starting in 1993 a new trend of slope and channel transformation has been strengthen. The disturbance of slope equilibrium by repeated heavy rains acting over the exposed bare bedrock and regolith facilitated the expansion of new erosional and depositional forms. These processes especially were active at the dismembered mountain front with alluvial-proluvial glacis at their base inclined 5–10%.

This aggradation proceeds upstream very fast, progressing into the hilly reaches. This tendency has been registered since long time especially in Lish and Gish river catchments (Dutt 1966; Basu and Ghatowar 1986; Starkel 1989). The fast transformation of slopes and channels is due to the clustering of events, which make impossible the revegetation and stabilization. So the situation is different to observed after 1968 event in the Darjeeling Hills (Froehlich and Starkel 1987). The lack of vegetation makes possible more frequent passing of thresholds and reactivation of forms and sediments also during the second order heavy rains (Table 4). Therefore at the mountain foreland the alluvial-proluvial fans grow continuously and faster, formed both by small creeks and large rivers. During this clusterings it was observed not only the simultaneous passing of thresholds in transformation of slope and channel systems in the hills (Starkel 1972a), but also the tendency to formation of one complex piedmont surface simultaneously by both the large and small rivers. The fluctuations of highest annual water level of the Torsa river at the mountain front (Fig. 6) reflect beside the aggradation trend and difference size of flood waves, also the fluctuations related to temporal channel incision and scouring.

The aggradation is most distinct just at the steepest portion of the mountain margin (Fig. 7). The aggradation rate fluctuates there between 0.11 to 0.36 m · yr^{-1}. The highest one was recorded on the Jainti river: 3.05 m during the period 1993–2000. At the distance of 20 km from mountain front

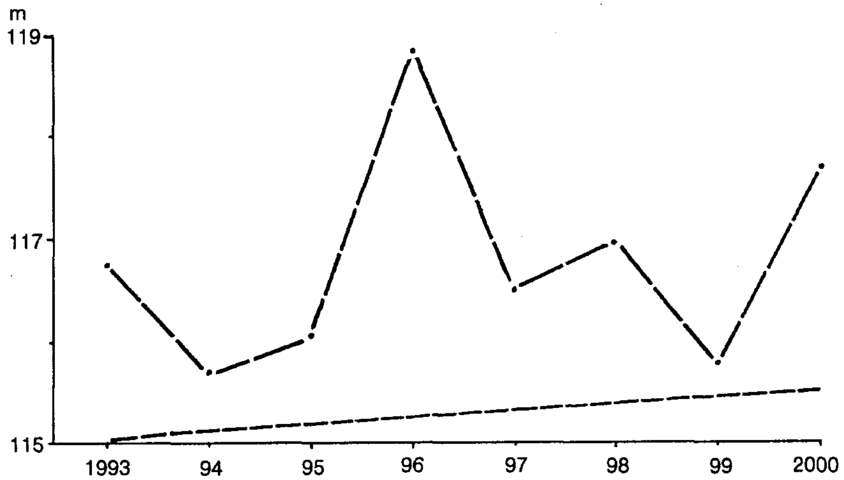

Fig. 6. Highest annual water level of the Torsa river near Phuntsholing (from 1993 to 2000)

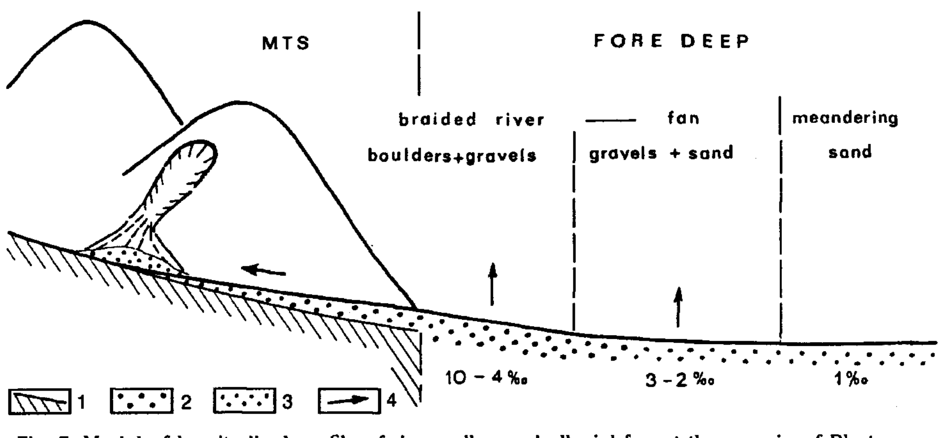

Fig. 7. Model of longitudinal profile of river valley and alluvial fan at the margin of Bhutanese Himalaya

it declines to 0.06–0.07 m · yr^{-1} (*Preparation*... 2001). Farther downstream the larger streams gradually deposit the coarser and then the finer material carrying finally sandy fraction and more or less on their half way to the Brahmaputra river change their channel from braided to meandering.

FINAL REMARKS

The gradual stabilization of slopes and gradual narrowing of channel cross-section at the margin of Bhutanese Himalaya would be possible after a distinct decline in the frequency of extreme rainfalls as well as revegetation of landslides and channel bars. The comparison with Darjeeling Hills west of the Tista river instruct, that the clustering of extreme events may play leading role in the less deforested catchments at the margin of Bhutanese Himalaya, where the repetition and acceleration of processes lead to faster aggradation in the Himalayan foredeep, progressing upstream to the hills.

The future research over neighbouring regions should show, how far the margin of the western part of Bhutanese Himalaya is exceptional in their appearance of clustering of threshold rainfalls. Or may be it is a normal way of evolution of the young mountain margin in the monsoon climate and similar clusterings may happen accidentally at different time in various parts of the Himalayan front.

In all comparisons also the influence of other local and regional controlling factors like differences in uplift rate, lithology and land use changes (cf. Bruijnzeel and Bremmer 1989) should be taken into consideration more precisely.

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STRESZCZENIE

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RÓŻNA CZĘSTOTLIWOŚĆ PROGOWYCH OPADÓW EKSTREMALNYCH PRZEKSZTAŁCAJĄCYCH BRZEG SIKKIMSKICH I BHUTAŃSKICH HIMALAJÓW

Badania prowadzone wcześniej w brzeżnej części Sikkimskich Himalajów wskazały na istotną rolę opadów ekstremalnych o wysokości 600–1500 mm w przekraczaniu wartości progowych decydujących o przekształcaniu stoków i den dolin. Ich powtarzalność co 20–50 lat prowadzi do etapowego odmładzania stoków i agradacji w dolinach, przegradzanych okresami stabilizacji.

W latach 1993–2000 u brzegu Bhutańskich Himalajów miały miejsce co najmniej trzy podobne zdarzenia ekstremalne. Ich kumulacja w czasie, mimo większego zalesienia obszaru, uniemożliwiła stabilizację i zarośnięcie stoków oraz obszarów zalewowych, prowadząc do kolejnego powiększania osuwiskowych dolin i poszerzania koryt roztokowych. Zdjęcia satelitarne wykonane w 2 różnych terminach pomogły śledzić kolejne etapy. Po trzecim opadzie progowym w lipcu 1998 roku doszło do połączenia osuwisk i spływów gruzowych w bocznych dolinach z ciągami akumulacyjnymi w dolinach dużych.

Zdarzenia ekstremalne, a szczególnie ich kumulacja w krótkim czasie u brzegu Himalajów, prowadzą ostatecznie do gęstego rozcięcia krawędzi gór i powstania złożonej powierzchni piedmontowych stożków, które przy wzmożonej dostawie zaczynają wnikać w głąb dolin górskich.