PROBLEM OF MASS-MOVEMENTS IN A PART OF KUMAUN HIMALAYA

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ABSTRACT

A greater than 13.1% reduction of protective forest cover on vulnerable hillslopes in 22 years (up to 1985), coupled with excavation for roads and canals, has greatly accelerated erosion in the catchment of the Gaula River, a tributary of the Ramganga in the Kumaun Himalaya. Fault-ridden tracts are experiencing severe mass-movements and attendant erosion. The frequency of landslides is 0.73 landslip/km^2 and the average rate of erosion is 170.3 cm/1000 years. Among other things, the generation of huge quantities of debris will reduce the carrying capacity of the river and the storage of the reservoir that will form behind the proposed dam at Jamrani.

INTRODUCTION

The setting

A Lesser Himalayan river, the Gaula drains a 600 km^2 area in the south-central part of Kumaun (29°17′36″–29°27′48″ N: 79°49′20″–79°26′ E) (figure 1), ranging in elevation from 500 m to 2610 m above MSL.

The average annual precipitation for the period 1958–1986 over the whole catchment area was about 209 cm, 70 to 90% of which occurred mainly in three months (mid-June to mid-September).

The catchment area falls in two well-defined lithotectonic belts. The Siwalik, constituted of sandstones and mudstones of the middle Miocene age, is sharply separated from the Lesser Himalaya by a deep tectonic plane known as the Main Boundary Thrust (MBT). The ruggedly mature but deeply dissected topography of the Lesser Himalayan subprovince is made of Precambrian sediments overlain by thrust sheets of metamorphic rocks and 1900 ± 100 and 550 ± 50 year old granites. The belt is cut by a multiplicity of faults and fractures with NW–SE, N–S and NE–SW trends, which play a very important role in the incidence of mass-movements (figure 2).

Land use pattern

In 1985 about 56.8% of the Gaula catchment area was under forests and 43.2% (table 1) was non-forested, the latter including 27.2% used for agriculture, horticulture and related purposes, and 5% converted into grazing land[1]. The agricultural fields are confined largely to river terraces and fan-shaped old landslide deposits where water is available.

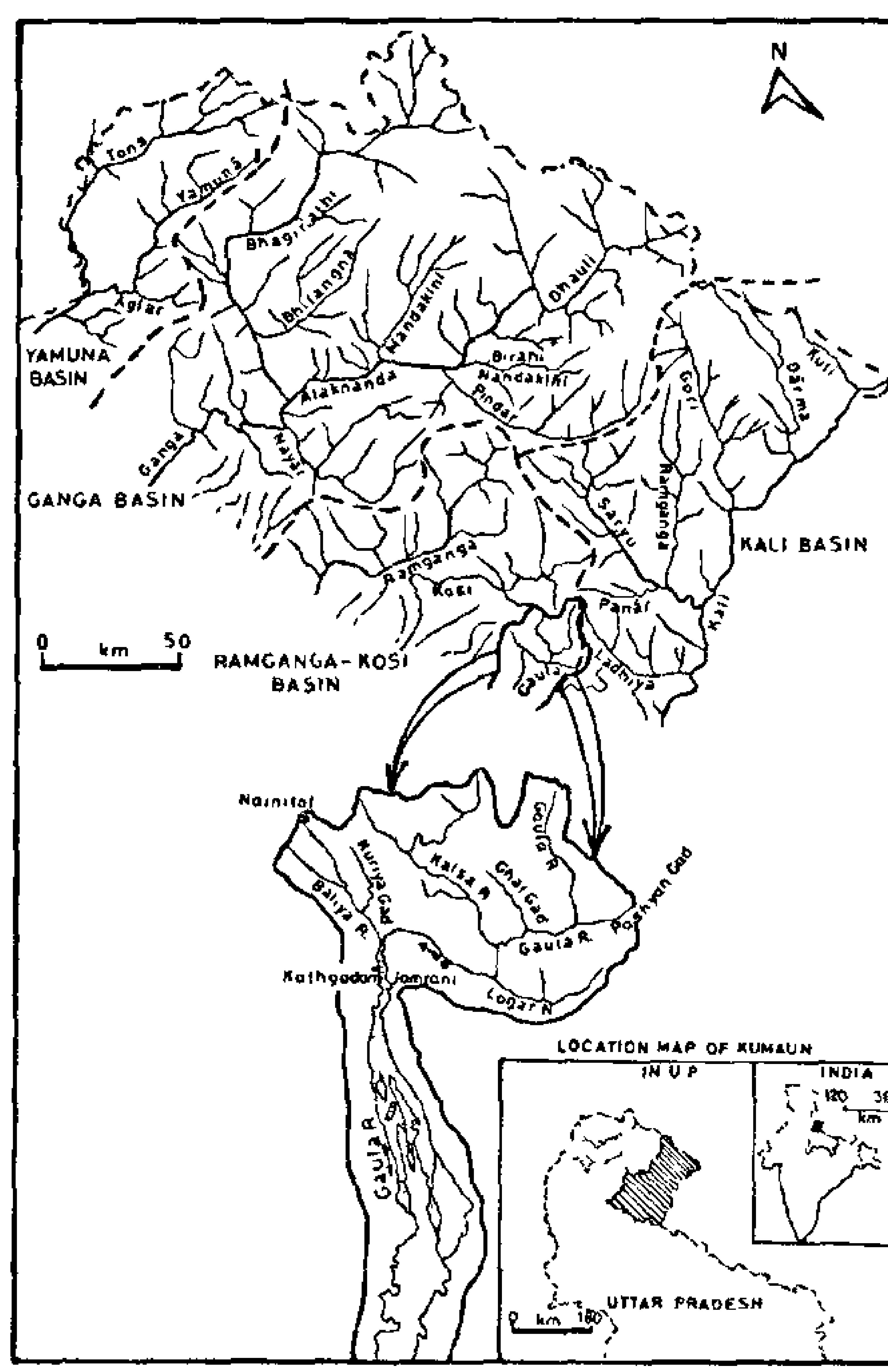

Figure 1. Location of the Gaula Basin in the Lesser Himalayan drainage network.

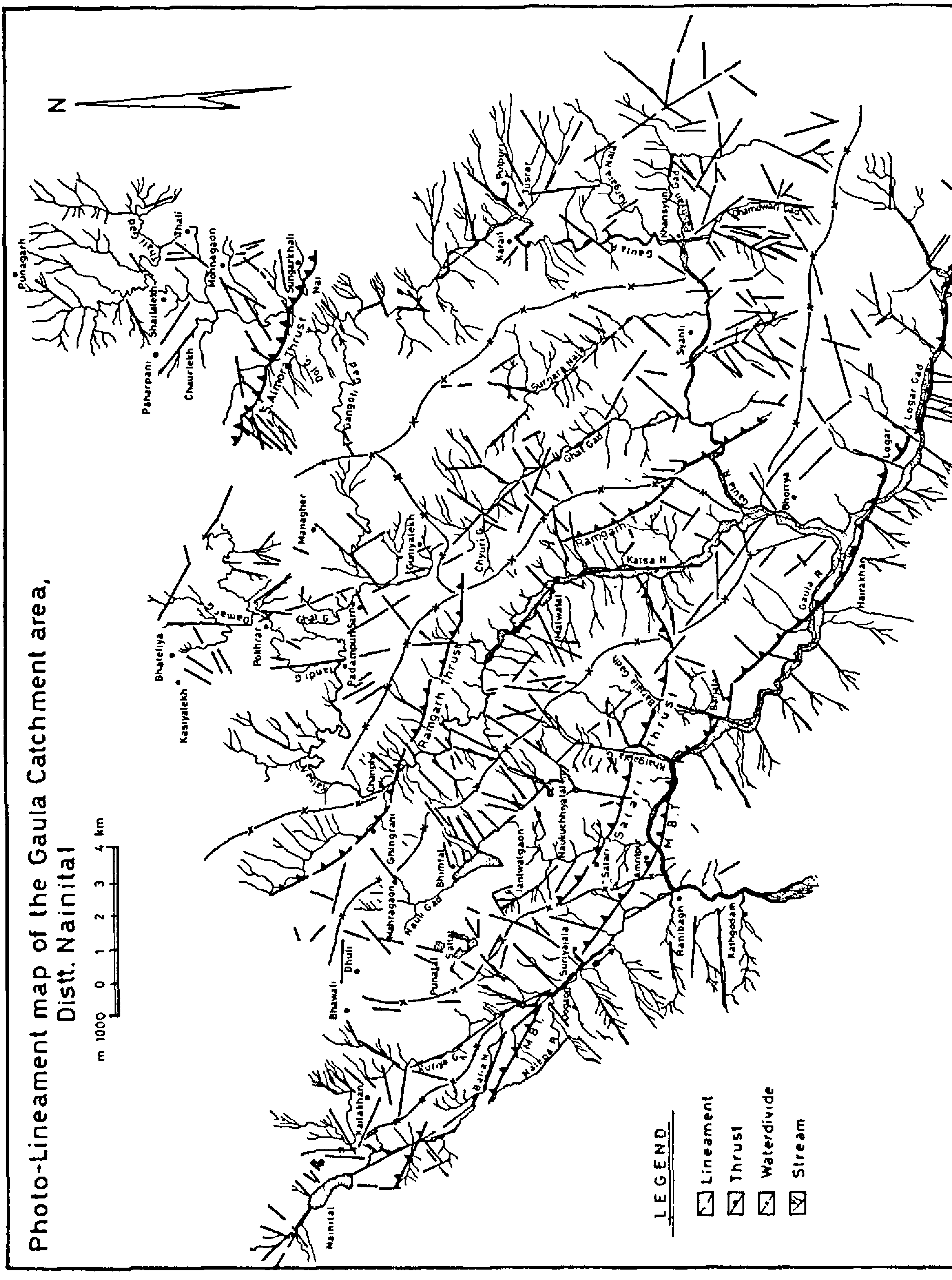

Figure 2. Thrusts, faults, fractures and related linears of the Gaula catchment.

Table 1 *Changes in the pattern of land use and reduction in forest cover in the Gaula catchment*

Land use	Area (km^2) 1962–63*	1973**	1985–86
Non-forest			
Agricultural land	121.01 (20.3)	139.6 (24.6)	162.37 (27.2)
Grazing land	23.49 (3.93)	25.46 (4.49)	30.06 (5.0)
Barren land	6.88 (1.15) }	14.47 (2.55)	11.67 (1.95)
Eroded land	3.25 (0.54) }		
Settlements	7.49 (1.25)	10.57 (1.86)	11.16 (1.87)
Roads	4.71 (0.79)	9.11 (1.6)	12.93 (2.2)
Lakes river beds	12.9 (2.14)	13.64 (2.4)	12.83 (2.15)
Total non-forest land	179.63 (30.1)	212.81 (37.5)	257.8 (43.2)
Forests			
Sal	29.13 (4.9)	81.14 (14.3)	22.86 (3.83)
Mixed sal–pines	15.56 (2.61)	31.52 (5.6)	8.6 (1.44)
Pines	239.93 (40.2)	83.5 (14.7)	179.2 (30.0)
Mixed pines–broad leaf	42.97 (7.2)	36.68 (4.46)	30.1 (5.04)
Mixed oaks–rhododendrons	40.73 (6.82)	98.75 (14.7)	37.3 (6.25)
Scrubs	49.29 (8.3)	23.22 (4.1)	61.4 (10.3)
Total forest land	417.61 (69.9)	354.81 (62.5)	339.4 (56.8)

Numbers in parentheses give area as percentage of study area; *Based on Survey of India Toposheet (interpreted by the present author[1]); **Compiled from Tiwari *et al.*[5].

Barren lands account for 6.95%, and major roads (approximately 350 km in aggregate length) cover another 2.2% of the study area (table 1).

In 22 years between 1963 and 1985, the forest cover shrank by 13.1% of the total area (table 1). The extent of land under agriculture increased by 7.1%, of the grazing land by 2.3%, and of other uses by 2.6%—all at the cost of forests.

PROBLEMS OF MASS-MOVEMENT

There has been a serious lowering of stability of many a hillslope in the Gaula catchment, leading to increased pace of erosion and incidence of slope-failures, particularly in the belt of the MBT and in fault-valleys such as of the Kalsa, Logar, Balia, and Bhimtal and Barajala streams. A study[1] of over 550 landslips and landslides, both old and active (> 25 m^2 in area), revealed that the slope-failures are related to slope angle, structural conditions of rocks, extent and nature of vegetation, and road construction. At present the frequency of naturally occurring and excavation-induced chronic landslides is 0.73 landslide/km^2 (table 2). Rockfalls and debris slides are most common (> 66%) on steep slopes, and the debris flows (> 5%) occur on weathered rocks and old landslide deposits, whereas slumps (> 15%) affect semiconsolidated old landslide-fans and cones.

Relationship with rainfall

Most of the landslides occurred during or immediately after heavy rains. Three factors, namely the intensity of storm periods, the amount of rainfall, and the duration of storm periods, affect the occurrence of landslides. Intense storms of even very short duration generated widespread landslides on roads during the rainy season (July–August) of 1985. A comparison of the landslide frequency on the roads during monsoon (2.71 landslips/km), with that of the post-monsoon period (October and after, 3.71 landslips/km) when 71 cm of rainfall occurred within 72 h, proved the point. It was noticed that the storms coming after prolonged rainfall generated more landslides than storms occurring at the beginning of the rainy season. In other words, landslides are more frequent when the ground is saturated with water.

STRUCTURAL CONTROL ON LANDSLIDES

The landslides are concentrated in fault-controlled

Table 2 *Frequency of active landslides in the Gaula basin*

Subcatchment	Area (km^2)	Number of landslides on natural slopes	Number of landslides on roads	Total number of landslides	Frequency (km^2)
Logar Nadi	47.5	70	6	76	1.6
Kalsa Nadi	141.2	89	13	102	0.72
Pashyan & Dhamdwanigad	38.65	11	4	15	0.4
Surgara Nala	22.14	6	—	6	0.27
Chyuri gad	22.73	11	21	32	1.41
Balia Nadi	81.3	60	21	81	1.0
Barajala gadhera	9.83	18	—	18	1.84
Khalghajala gadhera	6.92	9	—	9	1.3
Bhimtal gadhera	29.2	9	4	13	0.445
Gaula upstream of Khansyun	100.64	9	7	16	0.16
Gaula downstream of Khansyun	97.12	54	12	66	0.54
Total	597.2	346	88	434	0.73

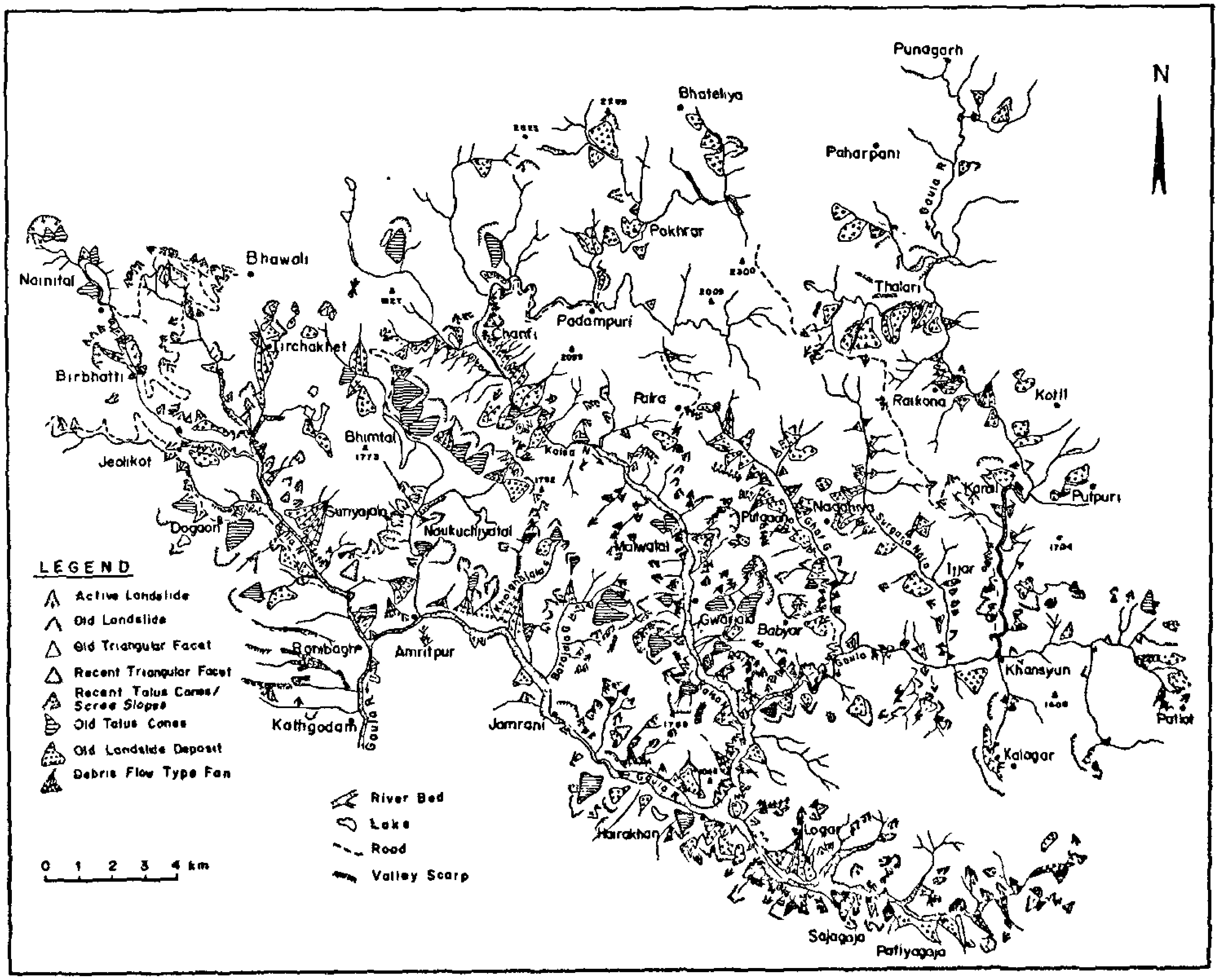

Figure 3. Highly fractured, sheared and crushed rocks in the proximity of the Kalsa Fault and Ramgarh Thrust are subject to recurrent mass-movements and severe erosion, as borne out by active landslides and their deposits in the Kalsa valley.

Table 3 *Sediment sources (number/km²) for various land use categories in the Gaula catchment*

Land category	Total area (km²)	Severity class (Number of sources/km²) 1	2	3	4	5	Total sources/km²
Barren land	11.67	2.23	1.2	0.685	0.17	0.086	4.37
Grazing land	30.06	0.789	0.47	0.033	0.067	0.033	1.4
River lake beds	12.83	2.42	0.78	0.78	0.234	0.312	4.52
Agricultural land	162.37	0.283	0.16	0.03	—	0.006	0.474
Roads	12.93	3.8	1.01	0.773	—	—	5.57
Scrub land	61.4	1.47	0.78	0.456	—	0.016	2.72
Forests	278.0	0.363	0.122	0.05	0.004	0.011	0.55

valleys (figures 2 and 3). As many as seven zones of major landslides have been identified (table 2).

IMPACT OF ROAD CONSTRUCTION

Geographical distribution of active landslides (figure 3) shows that about 20.3% of them occurred along roads and 79.7% on natural slopes (table 2). Landslides are frequent on newly constructed roads. Most of them occur on ancient landslide deposits, particularly where underlying or adjacent rocks are highly sheared. This fact indicates reactivation of old landslide debris.

In another survey[2] of road-induced landslides along two new highways it was noticed that the major environmental correlates of failures are slope height, slope of the roadcut, number of enlarged joints and extent of erosional undermining of the roadbeds. Slumping activity is negatively correlated with the upslope tree cover. The slopes of the older (>25 years) roads have already acquired vegetational protection and are thus relatively stable. However, erosion continues on bare slopes deprived of vegetation. It is noticed that the impact of newly constructed roads as a source of sediments is limited to the first five to six years after their construction.

HIGHER RATE OF EROSION

About 548 sources of debris generation have been identified (table 3). The number is smallest in the belt of the rocks of the Almora Group, which happens to be covered with forests of oaks and rhododendron, and largest (5.57 sources/km²) along the roads. The river terraces with scanty vegetation (4.52 sources/km²) and barren land (4.37 sources/km²) deprived of protective vegetational cover generate substantial quantities of debris that eventually flow down the streams and the Gaula. The zones of faulting and thrusting show the highest degree of erosion.

Table 4 *Total suspended load and erosion rate in the Gaula basin (area 597.23 km²)*

Month	Suspended sediments (in tonnes/month) 1985*	1986**
January	894.96	
February	84.54	
March	58.5	
April	27.4	
May	95.85	
June	254.14	266.34
July	8.82×10^4	8.96×10^4
August	136.0×10^4	141.0×10^4
September	36.6×10^4	32.7×10^4
October	50.9×10^4	26.6×10^4
November	1964.7	
December	342.2	
Aggregate suspended load	2.33×10^6	2.093×10^6
Bed load	0.466×10^6	0.42×10^6
Total sediment load	2.796×10^6	2.513×10^6

*Collected by present authors; **Gaula Barrage Circle, Kathgodam.

The rate of sediment transport in the Gaula river has been calculated on the basis of suspended load measured in 1985 and 1986, which were 2.33 and 2.1 million tonnes respectively (table 4). Applying the formula of Gregory and Walling[3] the average rate of erosion for the two years turns out to be 170.3 cm/1000 years. This figure is quite higher than those for the Brahmaputra (70–140 cm/1000 years) and the Saptakosi of Nepal (100 cm/1000 years)[4] determined more than two decades ago.

8 August 1988; Revised 24 October 1988

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5. Tiwari, A. K., Tewari, J. C. and Singh J. S., *Proc. Indian Nat. Sci. Acad. (Biol. Sci.)*, 1983, **49**, 336, 421.

NEWS

SESBANIA—A PROMISING NITROGEN-FIXING LEGUME

An aquatic legume *Sesbania rostrata* recently discovered in Africa, can be grown before or between rice or maize crops to bring nitrogen from the air into the field.

"*Sesbania* offers potential for farmers to grow their own nitrogen instead of depending on chemical fertilizers," says Dr J. K. Ladha, associate soil microbiologist.

"Unlike other green manure plants, *Sesbania* has nitrogen-fixing nodules on its stems and well as its roots," Ladha adds. In fact, *Sesbania* has 5–10 times more nodules than most legumes.

Sesbania combined with azolla can substitute for about 90 kg of nitrogen fertilizer per hectare, according to Dr Joven Lales, assistant professor at the University of the Philippines at Los Baños (UPLB). Lales works for the National Azolla Action Program on the use of *Sesbania* and azolla as green manure.

Because *Sesbania* grows to about 1.5 m tall in 45 to 60 days, it can fit between two rice crops at little extra cost to rice farmers.

Such a crop will fix 60–90 kg of nitrogen in a season. *Sesbania* can be drilled or broadcast in ricefields soon after harvest. About 25 kg of seeds will plant enough *Sesbania* to cover a hectare. The green manure crop may require one or two initial irrigations for sprouting and stand establishment.

Sesbania covers a field quickly, and can be incorporated into the soil in less than 2 months. If harvest is delayed beyond 2 months, the stem becomes tough and the crop is difficult to plow into fields. *Sesbania* grown to maturity reaches a height of 3 m and sets seeds in about 4 months.

Sesbania grown in late March or early April produces the most biomass. UPLB scientists say that vegetative growth can still be good even if *Sesbania* is planted as late as July. That schedule suits farmers with rainfed fields.

When *Sesbania* is grown for the first time, the rhizobium bacterium, which forms the nodules and fixes atmospheric nitrogen, must be applied—usually as a spray. Afterward, nodules form spontaneously. Rain seems to help spread the stem nodules.

"*Sesbania*'s unique system of stem nodulation may provide clues to genetic engineers trying to incorporate the ability to fix atmospheric nitrogen into grain legumes such as cowpea and soybean when grown under flooded conditions", Ladha says. (*The IRRI Reporter*, September 1988, 3/88; Published by The International Rice Research Institute, P.O. Box 933, 1099 Manila, Philippines.)