Kerala: *Cyanosarcina littoralis* Schwab. is a new record to the Indian subcontinent. A noteworthy feature of the species composition was their highly mucilaginous or ensheathed nature, perhaps an adaptation to the stressed environments. The solitary filamentous and less mucilaginous forms were usually found embedded in the mucilage of other cyanobacterial or eukaryotic algae.

The lowest pH at which CB were found growing was 2.8. Among the 240 composite samples, 68, 89, 65 and 18 respectively were from pH range 6–5, 5–4, 4–3 and 3–2.8. The relative abundance of CB and eukaryotic algae is presented in Figure 2. At pH 6–5, the counts of CB exceed those of eukaryotic algae. Minor variation was observed between the abundance of CB and eukaryotic algae at pH 5–4 and 4–3. However, at extremely low pH range (3–2.8), a major difference was observed in the counts of CB and eukaryotic algae. The lowest count (2.8×10^2 CFU/cm^2) of CB in pH range 3–2.8 was relatively high compared to the abundance in other stressed environments[13].

The available data exhibits the richness of CB in acid soils of Kerala. Several strains isolated from acidic areas have been reported to grow well at pH levels reaching original habitat[14], but the lowest pH was 4.8. However in the present study, cyanobacterial species were observed in samples with pH as low as 2.8. Rapid growth of some strains under laboratory conditions in a medium of low pH has been reported[15], and they maintained a high intracellular pH. This is indicative of an efficient internal pH-regulating mechanism in these rather rare strains.

The availability of certain nutrients, the water holding capacity and other conditions are influenced by high H^+ concentrations[16]. Algal cells are known to develop a certain electrical surface charge expressed as zeta potential[17], depending upon the pH of the surrounding medium, the size of which affects the permeability of the cell wall. Therefore the physiological adaptation of these CB strains towards the H^+ needs thorough investigation at the microenvironment level.

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Cost analysis of losses caused by the Malpa landslide in Kumaun Himalaya – A basic framework for risk assessment

Landslides, around the world, take a heavy toll on life and property every year. Indeed, they are one of the most significant contributors to aggregate national losses caused by natural disasters[1], both of property and lives (human as well as live stocks). The monetary costs associated with landslides result from damages to structures, loss of land and the loss of income accruing from the land, and disruption to communication routes. These also include the monetary costs associated with the loss of human and animal life. In the Himalayan region, landslides take place every year, and the nature and the factors, natural or manmade, responsible for generating these landslides are indeed diverse. Thus, the general strategies for hazard estimation do not seem feasible, and each case therefore requires to be studied in detail to work out the total incurred cost associated with landslide damages.

Hill-side instability is a common problem in the geo-dynamically sensitive belts of Kumaun Himalaya[2]. Several major landslides have occurred in the recent past resulting in large-scale damages to life and property. They are generally triggered by the raging torrents of petty streams, bringing enormous volumes of debris mixed with heavy blocks of fallen rocks and boulders that get detached from the constantly strained rock faces along the fault-carved Himalayan valleys[3]. A major tragedy took place on July 22–23, 1983, in the Karmi village, district

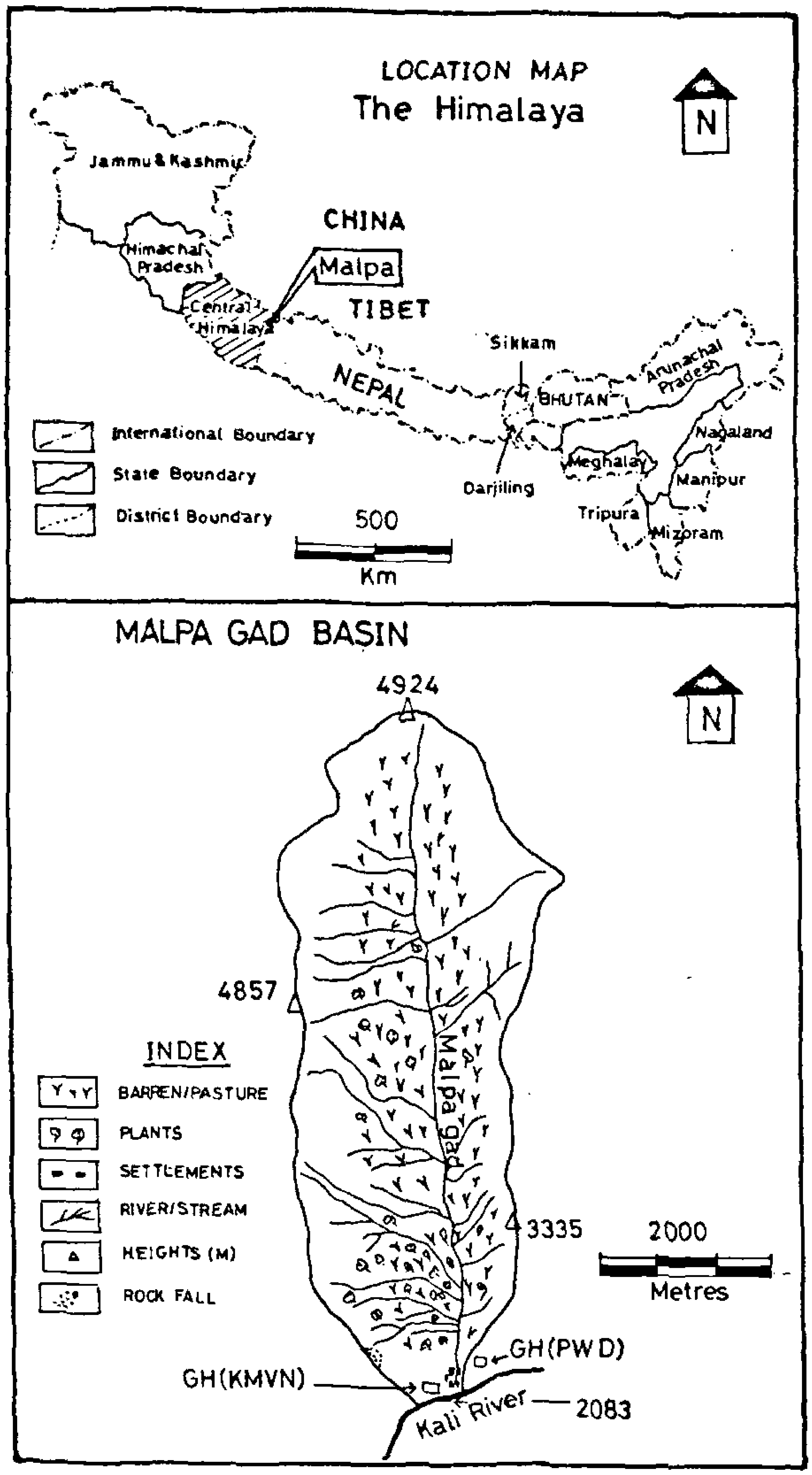

Figure 1. Location map.

Bageshwar, when a landslide, stretching for 4 km along the valley, swept the entire village in less than half an hour. This landslide was triggered by a high intensity rainfall which brought down the deforested hill top[4]. This region had, in fact, suffered several such events in the past, notably the 1977 Tawaghat landslides in the catchment area of the river Kali which took a toll of 44 lives and disrupted an area of 40 sq. km, and another one some year ago in the Phore Phenda village, which had previosuly killed about 150 people[5] in the same area.

Several studies have been carried out to evaluate landslide hazards in the sensitive zones of the Himalayan region, involving in-depth investigations of the of-lithology, geological structures, topographic setting, vegetation patterns, rainfall intensity and pattern, intensity of earthquakes, drainage patterns, and frequencies of past landslides in the area[3,6]. Anbalagan[7] has discussed various aspects of the landslide-hazard evaluation and suggested mapping techniques for landslide-prone zonation in the mountain regions. While most of the studies[8–10] have been qualitative in nature, some have attempted to define the cost attributes of landslides that have occurred in the past[11,12]. The present study was therefore conducted to analyse the total incurred cost that was associated with the losses resulting due to the Malpa landslide in the central Himalaya.

For this study, field surveys were carried out to collect the primary information from Malpa and the surrounding villages. A questionnaire survey was conducted in October 1998 to gather information concerning this event, and the extent of losses as a result of the landslide were obtained from the villagers and the dependents of the persons killed. Information was also generated through personal interviews with the watchman of the Public Works Department (PWD) guest house and other staff members present there at the time of this event. Data related to the land-use pattern in the area and the loss estimates computed by the State Government were collected from the records of the tehsil office, Dharchula. An attempt was then made to estimate the total incurred cost, in terms of money, in order to create a basic framework for future risk assessment in the region. The number of persons and animals killed in the accident were checked out from official records. The monetary cost associated with the missing livestock was worked out on the basis of their current price structure. Monetary losses incurred due to the land and human lives destroyed were calculated using the compensation value that was decided by the Government. Estimates of the loss in annual income by the people of the area, on the basis of number of piligrims to the Kailash Mansarovar (pilgrimage track) in a year, were computed by adding the annual income usually earned by porters and keepers of horses and mules at the rates as fixed by the UP Government. Thus the monetary losses associated with landslide damages were designated as private costs and public costs[11]: i.e. for the Malpa landslide, the compensation paid by the Government and the cost associated with the lost public properties were included under the public costs, whereas the cost of losses incurred by the local people, for which no compensation was paid by the government, was termed as the private cost.

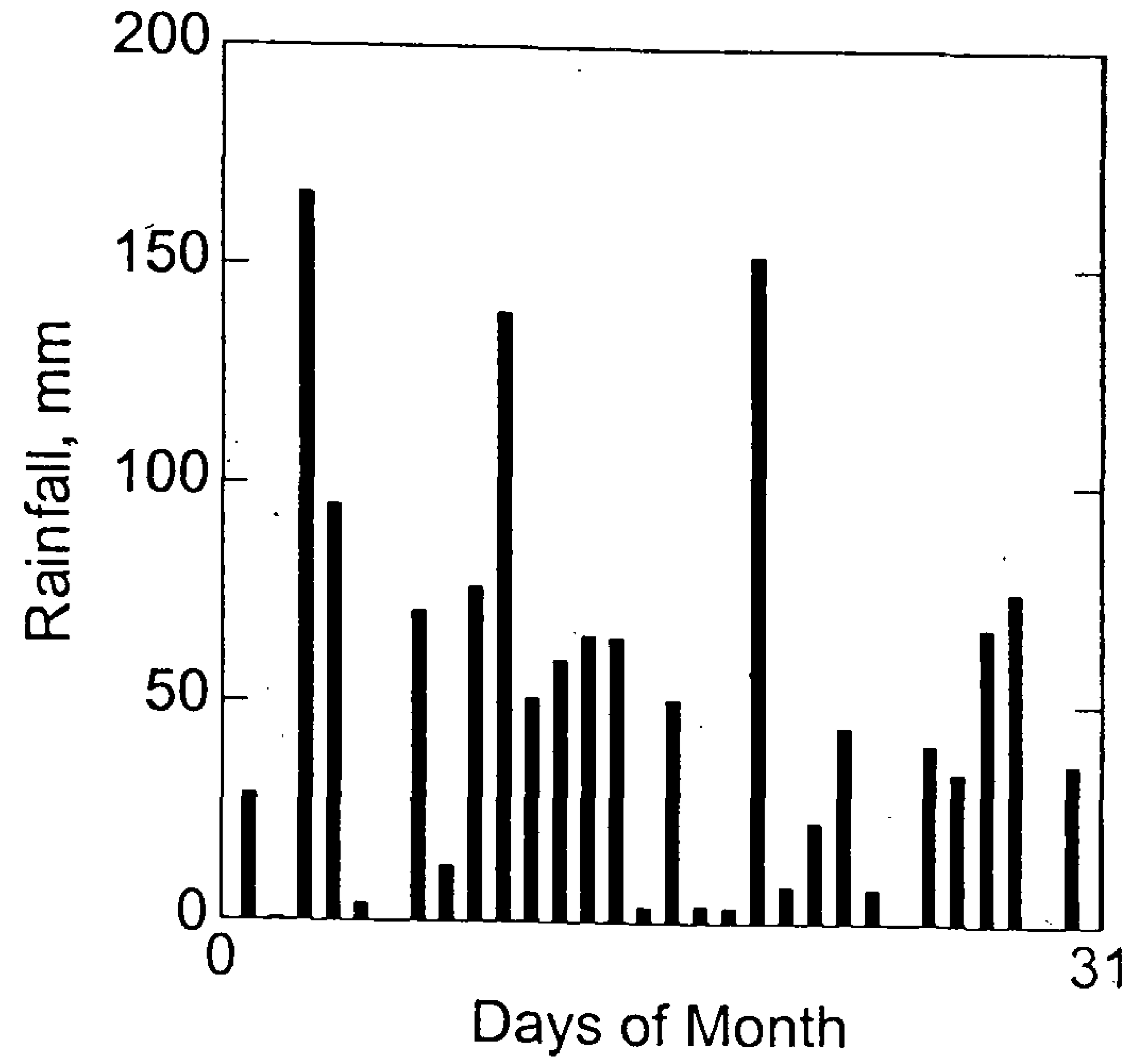

Figure 2. Rainfall pattern during August 1998 at Namik.

Malpa is situated (30°13′56″N, 80°48′25″E) along the right bank of the river Kali, at the confluence of the Kali and Malpa Gad (stream), 58 km from the Dharchula Tahsil (Figure 1). It covers an area of 2.951 ha with a population of 14 according to the primary survey in 1998. The Malpa Village is a small hamlet belonging to the Bundi revenue village. Its altitude ranges from 2065 to 2125 m above m.s.l. with an average slope of 15–20°. Though its climate data, at the time of landslide, was not available, 1386.87 mm of rainfall was recorded at the nearby Namik Village which has a similar environmental setting. The record of daily rainfall at Namik showed a heavy rainfall in the first half of August 98, which was perhaps the major factor responsible for the landslide (Figure 2).

The land-use pattern of the village before the landslide was: (1) 36.53 per cent of total village area not suitable for cultivation, (ii) 21.11 per cent of the area as cultivable wasteland, and (iii) 13.83 per cent under cultivation (Figure 3). About 10.57 per cent of the total village area was covered by human settlements and the remaining categories were: river (10.40%), footpath (4.75%), streams (2.71%) and rocky waste (0.10%). No area of the village was under forest cover. Major crops of the region included phaphar (*Fagopyrum tataricum*), palthi (*Fagophrum esculentum*), potato (*Solanum tuberosum*), and rajma (*Phaseolus vulgare*), etc. Additionally, some cash crops in the form of vegetables were also grown.

Geologically, Malpa lies on the SE face of a spur diverging from the Malpadhur range of the Great Himalaya and is located on the Kali Gorge along a major fault[13]. Several faults striking perpendicular to the mountain range (NNE–SSW and NNW–SSE) showing evidence of the neotectonic strike-slip movements and extreme shearing of rocks, have contributed to large-scale erosion and landslide[3]. Furthermore, the area lies in the Great Himalaya, close to the Pindari Thrust which is one of the several thrusts between the MCT and the trans-Himadari fault parallel to the mountain range. The complex intersection between the activity of this thrust and the closeby transverse tear faults have rendered this area extremely vulnerable to recurrent slope failures. The area has valleys with steep side walls together with immature drainage development, which shows high influence of tectonic activities[14].

The disastrous Malpa landslide was basically a rock fall from the nearby hill top, triggered by prolonged and heavy rainfall over the area[15]. Continuous rainfall, from Aug. 13–16, 1998, resulted in detachment of already precariously standing rock masses (quartzite interbedded with thin bands of garnet-bearing sericite schist) along a fault zone on the mountain slope[2,15]. Rock masses and boulders fell down up to a distance of 100 m towards the east and then branched into two different directions (northeast and southwest) after hitting a rock wall. The portion diverted to the SW blocked the footpath to Malpa, which greatly hampered the rescue work. The other portion, which was diverted to the NE direction, travelled a downward distance of about 150 m along the hill slope. The rock mass was finally deposited on the bed of Malpa Gad (stream), and temporarily dammed the Malpa Gad. A temporary lake so created in the Malpa Gad eventually bursted on the night of Aug. 17, 1998, causing a flash flood which washed away the village. A small lake with water marks on its walls still exists today as a mute witness to this course of events. The Malpa Gad changed its course as well, by about 14 m towards the west, due to the flood, dumping an enormous amount of debris on the flatter areas of the valley where most of the structures were located and the ill-fated people had taken shelter. The entire event took about 2.30 h, from 00.30 AM to 3.00 AM on August 17–18, 1998, resulting in complete destruction of life and property in the village (Figure 4).

Large-scale landslides often have disastrous effects on the natural environment as well as on man-made structures. Villages and towns, agricultural and forest lands, communication routes, water bodies, and human and animal population are threatened by such slope movements; underlining the social and economic significance of landslides. In the case of Malpa landslide, besides loss of human life and cattle, a large number of houses, huts and tents were destroyed by the flash flood and the debris flow (Table 1). The missing persons included 46 males and 14 female pilgrims, 8 Indo-Tibetan Border Police (ITBP) personnel, 4 police personnel, 5 staff members of the Kumaun Mandal Vikas Nigam (KMVN), 12 Nepal citizens (7 males and 5 females) and 118 local people (112 males and 6 females). According to the official records, 69

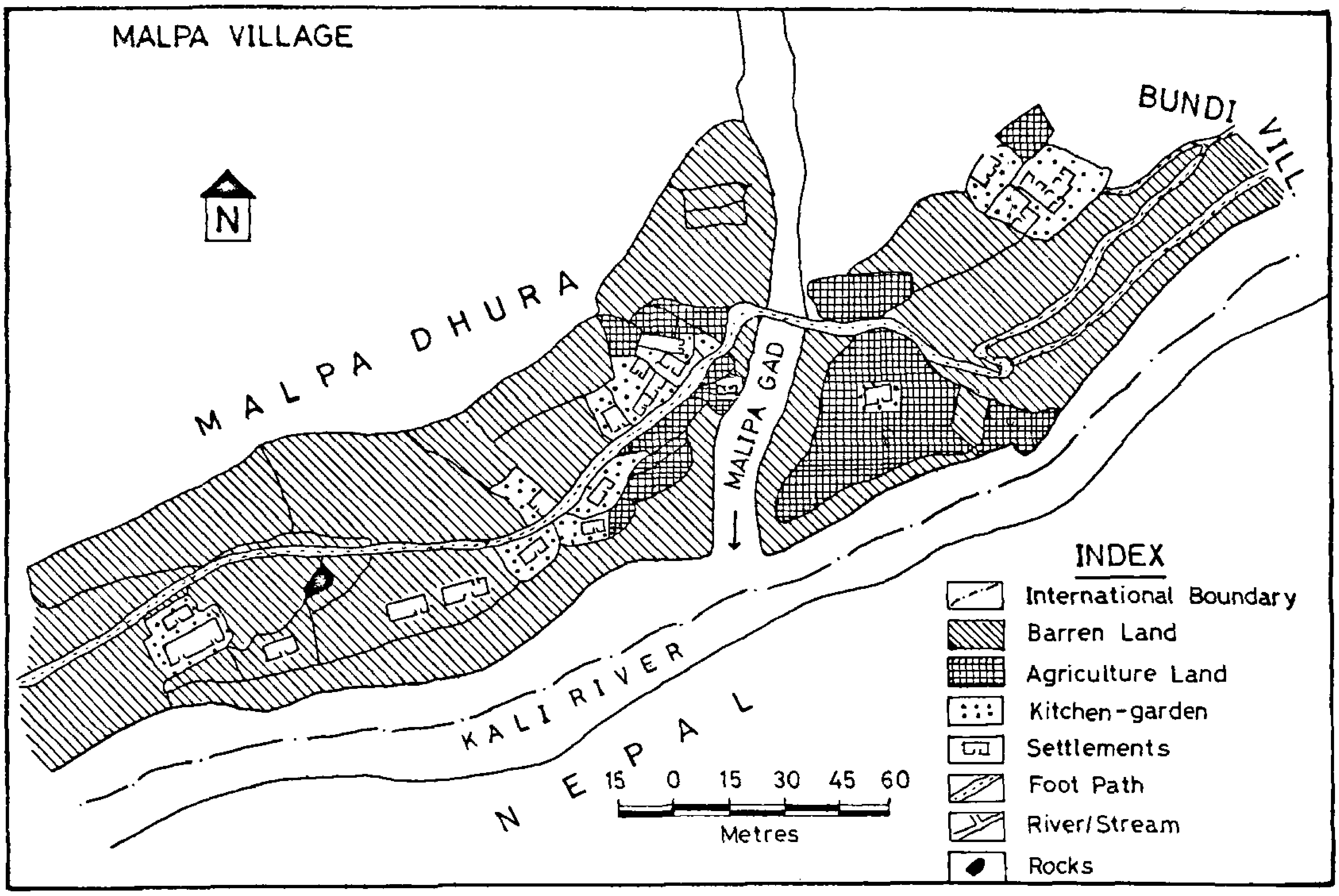

Figure 3. Landuse before landslide.

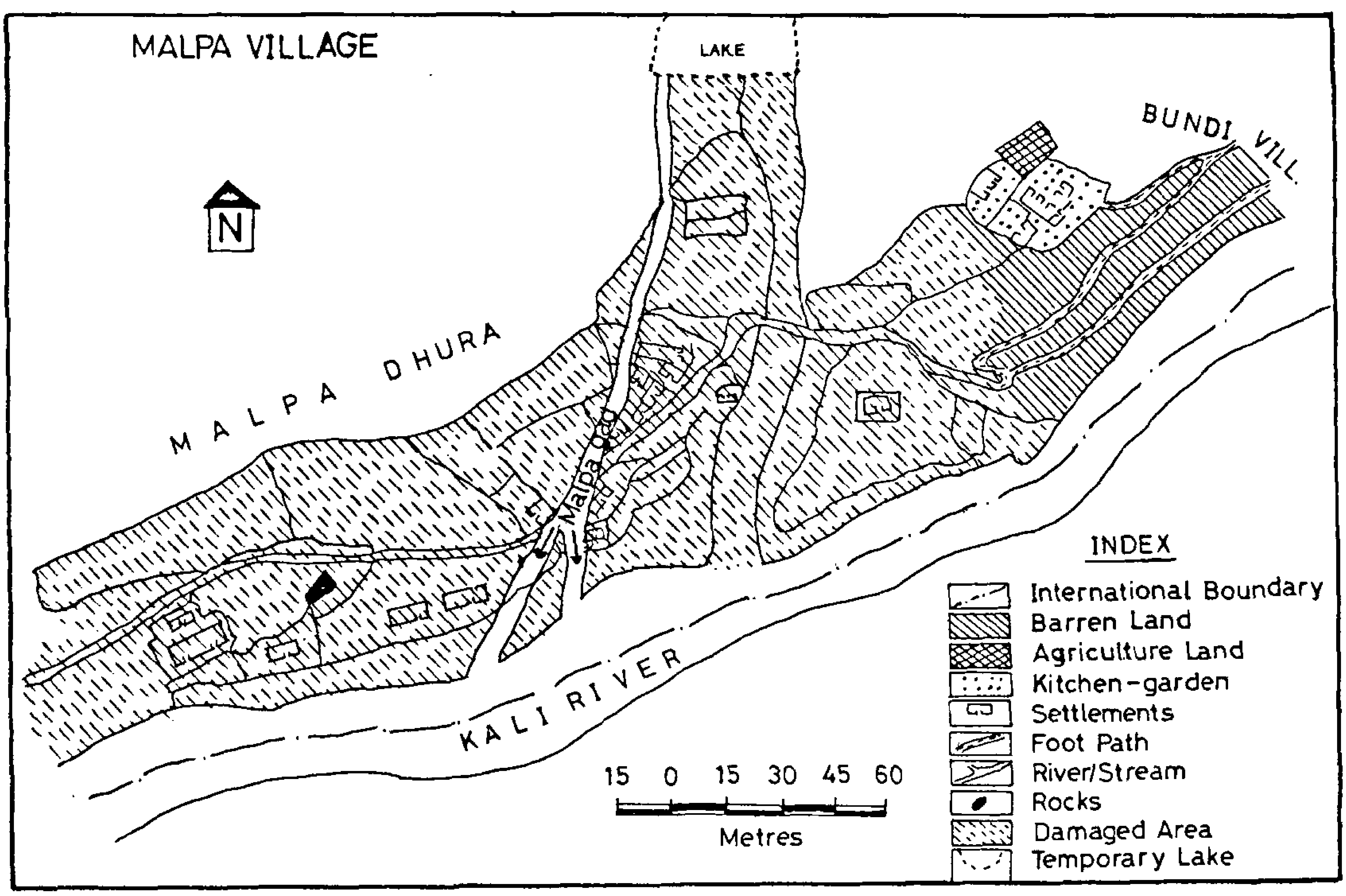

Figure 4. Landuse after landslide.

Table 1. Landslide damage at Malpa as per official records

Particulars	Details of damage (No.)
Missing persons	207
male	182
female	25
Animals	69
Houses	5
Huts (KMVN)	2
Hut (PWD)	2
Hut (Army)	1
Wooden bridge	1
Cultivable land	0.408 ha
Barren land	1.701 ha
Total land	2.951 ha

Table 2. Estimated costs of landslide damage at Malpa

Particulars	Public cost (Rs)	Private cost (Rs)	Total cost (Rs)
Livestock	1,38,000	9,22,650	10,60,650
Settlements	21,55,000	4,90,000	26,45,000
Arable land	–	60,430	60,430
Barren land	–	1,08,000	1,08,000
Plants/vegetation	–	28,500	28,500
Wooden bridge	1,00,000	–	1,00,000
Porter's income	–	3,26,700	3,26,700
Other items	6,00,000	7,64,923	13,64,923
Total	29,93,000	27,01,203	56,94,203.00

Source: Tahsil office, Dharchula, 1998 and Field survey, 1998.

animals (40 horses and 29 mules) were also buried under the debris of the landslide. In addition to this, 11 cows, 7 calves, 1 bullock, 7 goats, and 99 hens were also killed by the landslide which have not been included in the official list of losses.

Several assessment teams were sent out to the affected area by the UP Government, who assessed the cost of different types of losses separately as a result of this landslide. But, the cost associated with monetary compensation to kith and kin for the loss of their relatives has not been included in the total cost assessment. For example, loss of livestock (horses and mules only) was assessed by them to be Rs 6,12,500. This did not include those owned by the local people. Similarly, for the loss of properties, the cost of Government assets alone was included. Official estimates of the total loss of animal life and property was computed to be Rs 38,51,400, which was highly underestimated. However, loss of human life (207), of land (2.951 ha), of income from tourism and vegetation has not been included at all. A comprehensive assessment of the total incurred cost associated with landslide damage was therefore attempted for public costs as well as for private costs.

Under public costs we have included the cost of items that were borne by the State or Central Government, such as the cost of structures like the KMVN huts, army huts, communication routes, etc. as well as the monetary compensations paid for the loss of human and animal lives. The total public cost thus calculated was Rs 29,93,000 for properties (Table 2) and Rs 2,07,00,000 for human lives. The incurred cost associated with management, during and after the landslide, such as rescue costs, investigation costs, were not included in the above estimates due to nonavailability of reliable data. Losses to the various departments were worked out from the tahsil records: Loss to KNVN was the highest (Rs 15.00 lakh) followed by the UP PWD (Rs 6.25 lakh) and Indian Army (Rs 1.30 lakh).

Beside loss of human and animal lives, loss of agricultural and other categories also took place during the Malpa landslide. The village land which was covered by fallen rock mass and debris was completely damaged and was unsuitable for use in the near future. Thus, the cost of land (arable land, barren land, and vegetated land) has been included under private costs. In addition to this, the prevailing difference in market value and compensation cost for livestock has also been accounted for under private costs. The total private cost of livestock was thus worked out as Rs 9,22,650 (Table 3). While the loss in terms of agricultural land was Rs 60,430, loss in terms of land under plants and vegetation, and barren land was Rs 28,500 and Rs 1,08,000, respectively. The cost of private houses of 5 households was Rs 4,90,000, which was not compensated by the Government, and was to be borne by the five households depending upon the size of their houses (Table 4).

In addition to the above losses, substantial losses in income are expected to result due to discontinuation of trekking to Kailash Mansarovar in the future. Total loss of income of the local com-

Table 3. Cost of damage of livestock

Cattle	No. of cattle	Cost (Rs)
Horses	40	4,80,000
Cows	11	14,300
Mules	29	4,06,000
Goat/sheep	5	5500
Hens	99	14,850
Bulls	1	1200
Other (dogs)	2	800
Total	187	9,22,650

Source: Field survey, 1998.

Table 4. Cost of damaged private houses*

House holds/ (no. of houses)	Size of each house* (no. of rooms)	Cost (Rs)
1(1)	4	52,000
1(1)	6	79,000
1(1)	7	91,000
2(1)	8	2,08,000
3 (other includes hotel, etc.)	5	60,000
Total cost		4,90,000

*Construction material of all the houses was stone walls with mud plaster and slate roofs.

Source: Field survey, 1998.

Table 5. Expected loss of porter's income from pilgrims of 12th group

Category	No. of porters mules/horse	Income (Rs)
Porters	37	66,600
Mules	43	1,16,100
Horses	40	1,44,000
Total	120	3,26,700

Source: Field survey, 1998.

munity has thus been worked out as Rs 3,26,700 in the year 1998 (Table 5). This loss can become a recurring feature in future in case the Kailash Mansarovar route is changed.

Thus our study has revealed that the loss of life, loss of settlements and livestock are the major contributors to landslide costs in the region and more than 65 per cent of the total landslide cost is because of damage to settlements and livestock population. In India, the Government has to bear the major part of damage cost (about 66% in case of Malpa landslide). The cost of landslide damages at Malpa could have been greatly minimized if construction in landslide-prone areas had been avoided, and the hazard potential of the area timely recognized. It was observed that the underestimation of the landslide hazard potential, neglecting the recommendations made in the scientific reports prepared by the geological experts and overlooking the early signals of the catastrophe were responsible for the high cost of this hazardous event which became one of the biggest tragedies of recent times. Nonavailability of scientifically collected data related to past events, landslide costs, and absence of hydro-meteorological data, etc. were the major knowledge gaps which withheld advance planning for hazard mitigation.

Himalayan ranges are susceptible to landslides, rock fall, flash floods, etc. We therefore need to educate the people about mountain risks and hazards, and the possible ways of living with these hazards. Site-specific hazard zone maps on 1:50,000 scale can be prepared which will give a broad picture, and would consequently be useful for regional planning.

Immediate action is also needed to initiate scientifically designed mitigation measures to reduce the risk of such events in the future. Effective R&D efforts for management of the natural mountain environment are the crying human need of the region[16]. It is recommended that the programmes for identification of hazard zones, regular monitoring of deformation patterns along these identified zone to evaluate the probability of occurrence of landslides, creation of site-specific GIS-based landslide hazard zone maps, and assessment of risks faced by existing and future structures must be launched by pooling the scientific resources of various institutions and agencies in the country.

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