Intern. J. Environ. Studies, 2001, Vol. 58, pp. 343–355
Reprints available directly from the publisher
Photocopying permitted by license only

AUGUST, 1998 LANDSLIDE TRAGEDIES OF CENTRAL HIMALAYAS (INDIA): LEARNING FROM EXPERIENCE

PIYOOSH RAUTELA* and SUDIP K. PAUL

Wadia Institute of Himalayan Geology, Dehradun – 248 001 (India)

(Received in final form 2 April 2000)

During the monsoons of 1998 Central Himalaya was struck hard by landslides. Major incidences took place in Kali, Kaliganga and Madhyamaheshwar river valleys and the death toll in these crossed three hundred. Fieldwork undertaken in these valleys has brought forth interrelationship between various geomorphic parameters and the landslides. At the same time, it was observed that under compulsions of increasing population and fragmenting social set-up, traditional resource management strategy is often bypassed aggravating the problem. Based on these experiences and laboratory based GIS and remote sensing analysis of the parameters affecting landslides an anthropocentric approach for mitigating disasters in the region is proposed.

Keywords: Landslides; Geomorphic parameters; Resource management strategy; Mitigating disasters; Central Himalayas (India)

THE FRAGILE HIMALAYA

It is generally accepted that the natural environment of Himalaya is deteriorating. Several theories have been put forth to explain the causes. Ironically, several of the widely accepted assumptions for the deterioration are either without factual support, or are demonstrably unsupportable [1]. There are, however, clearly visible negative changes in the resources and the environment of Himalaya. Compared to the situation 50 years ago, the extent and severity of landslides in the region is higher, water flow in traditional community irrigation

*Corresponding author. e-mail: bswihg@nde.vsnl.net.in

Intern. J. Environ. Studies, 2001, Vol. 58, pp. 343–355
Reprints available directly from the publisher
Photocopying permitted by license only

AUGUST, 1998 LANDSLIDE TRAGEDIES OF CENTRAL HIMALAYAS (INDIA): LEARNING FROM EXPERIENCE

PIYOOSH RAUTELA* and SUDIP K. PAUL

Wadia Institute of Himalayan Geology, Dehradun – 248 001 (India)

(Received in final form 2 April 2000)

During the monsoons of 1998 Central Himalaya was struck hard by landslides. Major incidences took place in Kali, Kaliganga and Madhyamaheshwar river valleys and the death toll in these crossed three hundred. Fieldwork undertaken in these valleys has brought forth interrelationship between various geomorphic parameters and the landslides. At the same time, it was observed that under compulsions of increasing population and fragmenting social set-up, traditional resource management strategy is often bypassed aggravating the problem. Based on these experiences and laboratory based GIS and remote sensing analysis of the parameters affecting landslides an anthropocentric approach for mitigating disasters in the region is proposed.

Keywords: Landslides; Geomorphic parameters; Resource management strategy; Mitigating disasters; Central Himalayas (India)

THE FRAGILE HIMALAYA

It is generally accepted that the natural environment of Himalaya is deteriorating. Several theories have been put forth to explain the causes. Ironically, several of the widely accepted assumptions for the deterioration are either without factual support, or are demonstrably unsupportable [1]. There are, however, clearly visible negative changes in the resources and the environment of Himalaya. Compared to the situation 50 years ago, the extent and severity of landslides in the region is higher, water flow in traditional community irrigation

*Corresponding author. e-mail: bswihg@nde.vsnl.net.in

systems (*gul* or *kul*) is lower, yield of major crops in the mountains (except in highly patronised pockets) are lower, diversity of mountain agriculture is reduced, the regenerative processes based on organic linkages between different land based activities have weakened, the inter-seasonal hunger gap (food deficit period) is longer, the time spent by villagers in fodder, fuelwood and water collection is longer, the botanical composition of species in forests and pastures has undergone negative changes, and finally the extent of poverty, unemployment and outmigration of people are higher in the hills. Himalaya is thus threatened with an ecological disaster. Step by step, nature is being destroyed and human, terrestrial and aquatic life is being shortened by the effects of development in the form of landslides, sedimentation, eutrophication of reservoirs, lakes and rivers, drying up of springs, and others [2]. Conventional development paradigm has thus failed to take into account mountain specificities such as inaccessibility, fragility, marginality, diversity or heterogeneity, niche or comparative advantage, and human adaptation mechanisms. Of the specificities fragility (of the terrain) is of immediate concern and is expressed in recurring hazards that the region faces. These natural hazards are often aggravated by anthropogenic activities and take heavy toll of human lives, infrastructure and natural resources.

The fragility of the region stems mainly from the geological history and evolution of the terrain. As the Tethyan Sea intervening inbetween Indian and Asian plates closed due to the plate motion mammoth blocks of rock masses moved southward for tens of kilometres. This movement of the earth blocks initiated many a weaknesses in the rocks of the region. From the Indus Suture Zone (along which the two plates are welded) southward Tethyan Thrust (TT), Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Himalayan Frontal Fault (HFF) form the major tectonic discontinuities along which major movement has taken place. Besides these there are numerous thrusts and faults intervening inbetween. These have rendered the terrain highly folded, faulted, fractured and sheared; and thus fragile.

Fragility is thus associated with the terrain and the people inhabiting these mountains have over the generations adapted their lifestyles and have learnt to live and cope up with the terrain. Through experimentation and accumulated knowledge of generations they evolved their own traditional ways of overcoming the handicap imposed by the mountain specificities. The people well understood the relationship between the water entering the surface and recharge of the aquifers and also the downslope mass movement. The recharge zones of springs were protected at various locations by invoking divine sanction and at the same time in order to safeguard habitations at vulnerable locations people devised ways of diverting rainwater directly into the main stream through a network of channels. This helped in keeping the pore water pressure within the threshold limits and the mass movement was averted. Such drains, locally referred to as jungle *guls* were observed in Ransi village (Madhyamaheshwar valley) while those at Kalimath and Jaggi-Bagwan have ceased to exist. These were built and maintained by the community without any support from the state and were regularly repaired and cleared before the onset of monsoon. The traditional system however collapsed with the onslaught of modern state oriented system.

TRAGEDY OF 1998 MONSOONS

The fragility of the mountainous terrain together with the vulnerability of the people habitating it was highlighted in August, 1998 landslide tragedies that occurred at Madhyamaheshwar and Kaliganga valleys of Garhwal Himalaya and at Malpa in the Kali valley of Kumaun Himalaya (Fig. 1). The death toll in these tragedies surpassed all previous highs and crossed the 300 mark.

In the Kaliganga and Madhyamaheshwar river valleys of Garhwal Himalaya landslides took regional dimensions and lower reaches of both the valleys were devastated. Major devastation took place on 11–12 August, 1998 (Fig. 2). The lush green valley was scarred deeply by the slides and a large proportion of the agricultural land was lost together with 62 human lives. Most of these slides initiated at the steeper slopes of the valley and the rolling down debris took devastating proportions. As if it was not enough a massive landslide near Bheti village on 18–19 August, 1998 blocked the course of Madhyamaheshwar river for about 24 hours (Fig. 3). In this incidence the whole mountain side, that was probably weakened by 1991

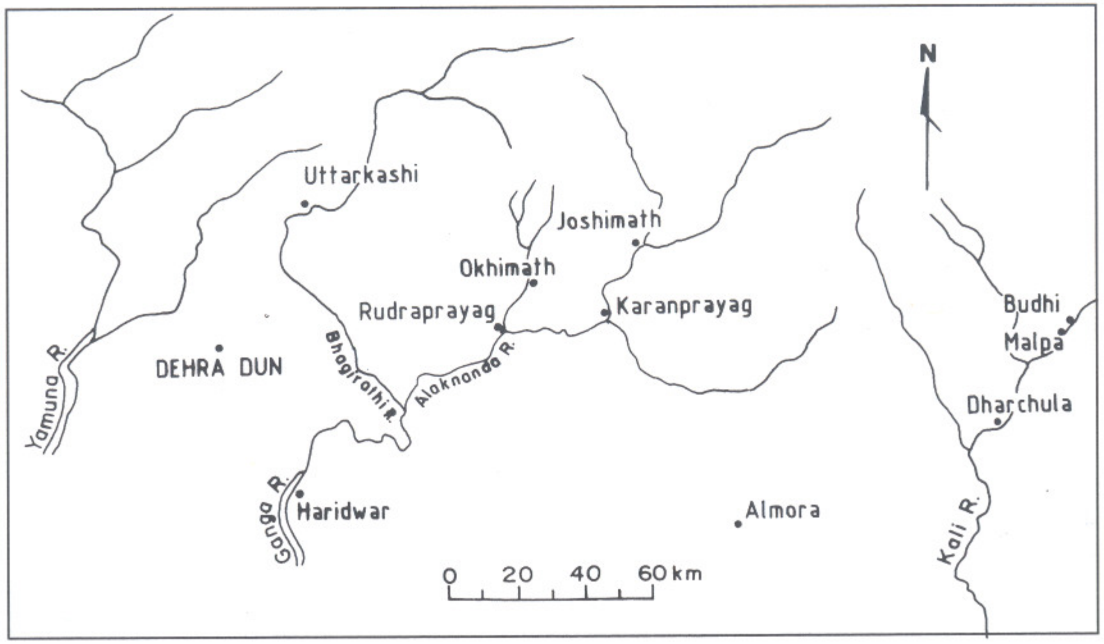


FIGURE 1 Location map of the areas discussed.

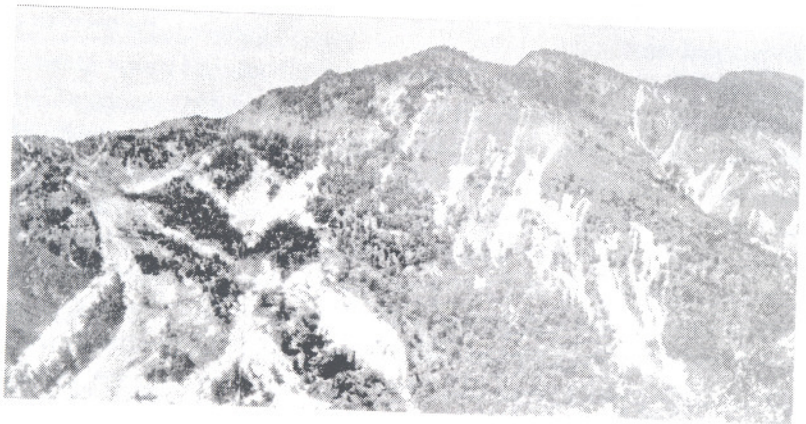


FIGURE 2 View of the landslides in Madhyamaheshwar valley.

FIGURE 3 View of the Bheti landslide that blocked the course of Madhyamaheshwar river on 18–19 August, 1998.

Uttarkashi earthquake (Magnitude 6.1 on Richter scale) and had reportedly developed cracks amid forestland, broke off ravaging three habitations (Bheti, Pondar and Sem). The debris glided upslope on the opposite bank burring alive the inhabitants of these villages without any trace. This incidence pushed the death toll over the hundred mark and changed the entire geomorphic set up of the surrounding area; the agricultural lands and habitations being replaced with heaps of boulders and debris and the two streams that once used to meet Madhyamaheshwar disappear amid heaps of debris. Three sets of joints were observed in the rocks hosting this slide and the water percolating through these facilitated movement along one of the dominant and pre-existing weak plane while toe erosion by the river triggered the movement.

In the Kali valley though the mass movement occurred at many places but by virtue of being sparsely populated these did not cause panic except the one at Malpa (an important transit point on way to Tibet) that took the inhabitants by surprise. At Malpa there were stray incidences of rockfall prior to the main tragedy and the rockfall of 18th August, 1998 that wiped out the ill-fated 12th batch of Kailash–Mansarovar pilgrimage. Death toll in this tragedy alone crossed the 200 mark and the course of Malpa gad (stream) was changes and the habitation of Malpa was ravaged.

SOME OBSERVATIONS

Both the Bheti and Malpa slides took place with a thunderous sound of rolling boulders and were accompanied by dust storm that covered a radius of more than two kilometers. In the Malpa slide storm was particularly severe and friction amid the rolling boulders produced twinkling effect.

The relationship between landslides and landuse show that the landslides are not confined to a particular landuse type. In Kali valley barren land accounts for most of the slides but in both the valleys in Garhwal landslides are almost evenly distributed amongst all the landuse classes with majority being confined to the agricultural lands.

The relationship between landslides and aspect of the slope show that both the valleys of Garhwal (Kaliganga and Madhyamaheshwar) show concentration of slides on easterly and southeasterly aspect

($> 50\%$). These are the slopes that have maximum area under agriculture. In Kali valley southwesterly aspect shows maximum slides (25%).

Correlation of landslides with the slope amount shows that moderate slopes in Kaliganga valley (41%) and gentle slope in Madhyamaheshwar (31%) and Kali (42%) valleys show predominance of landslides. In both the valleys of Garhwal (Kaliganga and Madhyamaheshwar) these slope classes have maximum area under cultivation.

The foregoing data clearly shows that there is something wrong with the agricultural practice as most landslides correlate positively with the agricultural land. Population pressure has perhaps compelled masses to undertake cultivation on slopes that are untraditionally considered unfit for such an activity. Most of the agricultural land that is devastated by the landslides falls under high slope category. Natural compulsion of bringing more land under cultivation forces increase in the height of the embanking walls of the terraces. This in turn adds to the instability of these terraces. Water imponded in these soils due to prolonged rains further added to the unstability of these slopes.

Going through the landslide record one easily gathers the fact that most of the slides take place during the rainy season. It therefore becomes imperative to check in for anomalies in the rainfall record. There are two zones of maximum precipitation in Himalaya; one near the foot of the mountains and another at an elevation between 2000 to 2400 m [3] and major portion of the area under present focus falls in the high rainfall zone. The rainfall data shows that the rains were on the higher side this year during July–August (1421 mm). The first fortnight of August recorded more than 300 mm of rains. There were incessant rains for weeks before the incidence and the pore water pressure crossed the threshold. Water gushing out in the downslope regions was observed at many places together with the seepages in the fault scrap of the Bheti slide that blocked the Madhyamaheshwar river course. Water lubricated the weak planes and the load of the water saturated mass resting on the steep slope increased beyond the threshold limits. Besides the role played by excessive precipitation, the region is pervaded by a large number of secondary weaknesses (Fig. 4) that played a significant role in mass movement.

In all the areas that are taken up for this study direct evidences of deforestation were not witnessed. Massive landslides were witnessed amongst well forested areas; *e.g.*, Bheti slide (Fig. 3). There is however

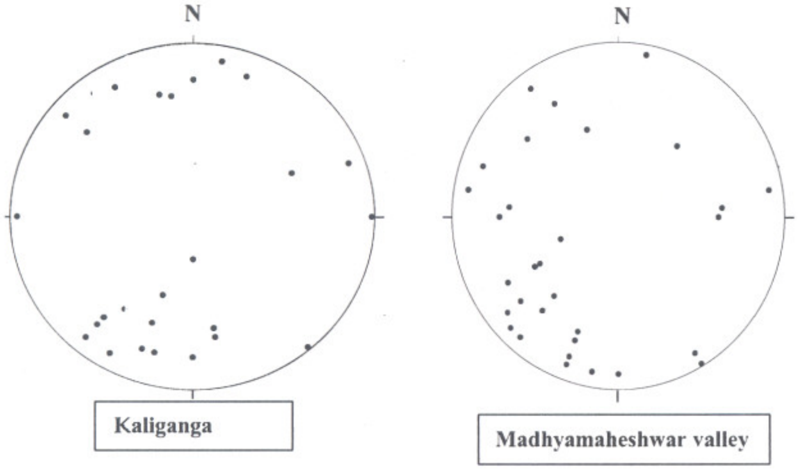


FIGURE 4 Poles of the joint planes in the vicinity of the Bheti slide.

no denying the fact that with the growth of population people have encroached the forest land and have resorted to terrace cultivation on steep slopes. During the monsoons of 1998 the region experienced concentrated precipitation within a time span that saturated the soil. Increased weight of the saturated soil under its own load destabilised terrace walls and the gushing water set the whole process of devastation.

REASONS AND MITIGATIVE STRATEGY

As stated earlier geological history of the terrain mainly dictates the fragility of the terrain [4, 5] and the present study also reasserts the same. In both the valleys of Garhwal Himalaya most slides are observed to be confined to highly sheared and fractured rocks of Munsiari Formation. As also pointed out by the previous workers Malpa rockfall is tectonically controlled [5, 6]. This fact is highlighted in the digital terrain model (DTM) by structurally controlled abnormally straight course of Malpa gad.

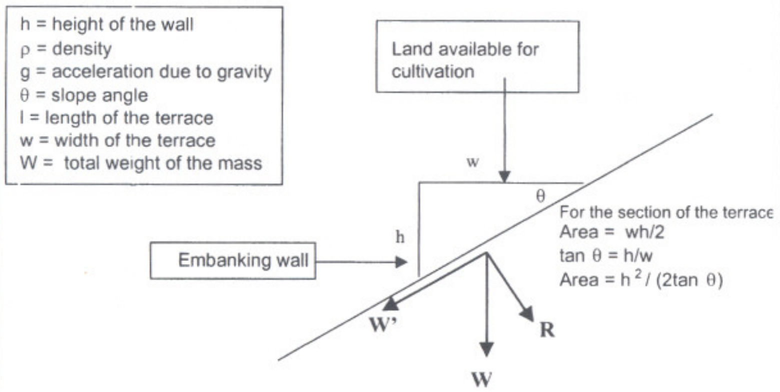
There is a marked positive correlation between the distribution of landslides and landuse; the barren land in Kali valley houses most of the slides while in Kaliganga and Madhyamaheshwar valleys most slides are confined to agricultural lands. This very fact makes the populace of the latter valleys particularly vulnerable to landslides. Agriculture is the sole source of livelihood in Himalaya and under compulsions of increasing population agriculture is often resorted to in steeper slopes violating traditional landuse dictums. This trend seems to have gripped the entire Himalayan terrain and to relieve pressure upon land there is an urgent need for promoting non-land based economic activities in the region.

A combination of factors, both natural and anthropogenic, have contributed to the present tragedy. Mounting pressure of population has forced people to practice agricultural activities on adverse slopes in the geologically and structurally fragile terrain of Madhyamaheshwar and Kaliganga valleys. The height of the embanking walls of the agricultural terraces has to be increased proportionally with to the slope in order to bring equal area under cultivation (Fig. 5). These terraces are in a destabilised position due to the mass of the soil and persistent rains saturating the soils only added to this. It was easy for the seasonal streams with high gradient to erode these terraces and trigger downslope movement. This process of mass movement was observed betweem Bedula and Rau-Lek in Madhyamaheshwar valley and between Bedula and Kalimath in Kaliganga valley. Traditional practice of maintaining jungle *guls* would have probably checked the level of saturation of the soils and the tragedy would not have taken this dimension.

The giant landslide that blocked Madhyamaheshwar is typical of slope failures in the Himalaya. This landslide occurred on a slope that was covered with moderately good forest. According to the local people a fissure running parallel to the valley was seen above the village after Uttarkashi earthquake. Toe erosion by Madhyamaheshwar river only destabilised the slope and initiated movement along these preexisting weak planes. Similar slides of smaller dimensions were also witnessed in the vicinity of Ransi village in Madhyamaheshwar valley.

The composite mass movement (rockfall and debris flow) at Malpa in the Kali valley is structurally controlled while land subsidence near Garbyang is initiated by toe erosion by Kali.

The Kali river flowing E–W is eroding the varve deposits at Garbyang from the base and thus the mass from the north is moving down. This movement expresses itself in the folding of the sediments.



Weight of mass behind the embanking wall of the terrace = $(h^2\rho g / (2\tan\theta)) \int dl$
Water imponded in the soils enhances the weight and thus adds to the unstability.
The water at the same time decreases the friction, thus adding to the instability.
$W' = W \sin\theta$
$R = W \cos\theta$
Downslope creep begins as $W' > R$
For angles $> 45^\circ$; $\sin\theta > \cos\theta$
So slopes at angles more than 45° are in a naturally unstable position.
The height of the embanking wall must increase by a factor
$(\tan\theta + \tan d\theta) / (\tan\theta - \tan^2\theta \tan d\theta)$ for an increase of $d\theta$ in the slope in order to ensure equal area under cultivation.

FIGURE 5 Mathematics of terrace instability.

This movement is threatening the very existence of Garbyang village. The pace of this movement can be checked by protecting the northern bank of the river by mechanical measures.

Excessive water percolating underneath the ground has played a major role in these mass movements. At present many governmental as well as non-governmental agencies are supporting developmental initiatives in the Himalayan region that seek to maximise recharge of groundwater during rains so as to be available for productive purposed during lean periods, through a series of engineering, vegetative and allied activities in the watershed. Studies on Himalayan agriculture in Central Himalayan sector (Nepal) have revealed that the terraces, especially on rainfed land, are often consciously kept outward rather than inward sloping and do not have a grassed bund on the edge to ensure that the crops are not damaged by water logging. The farmers are well aware that an increased accumulation of water on terraces would greatly accelerate the problem of landsliding by increasing the degree of soil saturation and adding weight of the ponded water itself [7, 8]. The monsoon rain is therefore deliberately intended to run off the outward sloping terraces. The farmers traditionally do not engage in the bunding of hard to manage, far flung fields in the hilly terrain for the fear of downslope movement due to the enhanced weight of the saturated soils. In the valleys under focus (Madhyamaheshwar and Kaliganga) also rather than conserving the precipitation recourse was traditionally taken to easy dispersal of the excess precipitation through jungle *guls*. The strategy of development in the hilly regions thus needs reorientation, and water management needs to be given top priority. Participation of the masses, and revival of the traditional practice of maintaining jungle *guls* needs promotion for it is the most cost effective and time tested mitigative measure.

Though there exists no record of seismicity associated with present slides, the region lies in a seismically vulnerable zone and these slides might well be reflections of the internal turmoil deep within the earth. The region has been seismically active in the past and Madhyamaheshwar and Kaliganga valleys experienced mild seismic tremors after the major landslide events (in November, 1998). Kaliganga and Madhyamaheshwar valleys suffered losses during the 1991 Uttarkashi earthquake (Magnitude 6.1 on Richter scale) and the effects of 1980 Dharchula earthquake (Magnitude 6.3 on Richter scale) were felt as far as Garbyang (where evidences of co-seismic slip are recorded) in the Kali valley. Moreover the epicentre of March, 1999 Chamoli earthquake (Magnitude 6.8 on Richter scale) does not lie far off from this region. Microseismic studies are therefore warranted in the region.

Fieldwork, supplemented by the analysis of the secondary and primary data under GIS environment has helped in preparing landslide hazard zonation maps for Kaliganga, Madhyamaheshwar and Kali valleys. Risk maps have also been prepared for the former two valleys considering population as the sole criteria as most infrastructure is closely interwoven around population centres.

Nature is known to give enough warnings to people to rush to safety. We however often tend to overlook the message of nature and are caught unawares. There were rockfalls in Malpa nala on 4th August, 1998 and on 14th August, 1998 that were grossly ignored. In Madhyamaheshwar as well, open fractures in the forest above the Bheti slide and stray incidences of creep and slide were ignored. These precursors to the massive sliding, if reported timely and taken seriously would have averted loss of human lives. There is thus a need of sensitising masses towards the potential hazards to which they are exposed, apart from delivering mitigative and relief know-how. In the case of most Himalayan tragedies communication network is snapped off and rescue takes too long to reach the affected people. In most cases survivors of the tragedy turn out to be the potential relief and rescue workers. The efficiency of these can be greatly enhanced through an organised training drive.

Interestingly, all the dogs of Malpa village rushed to safer locations and reportedly none suffered casualties. These animals are known to sense earthquakes well in advance. They certainly sensed the slides well in advance as the disaster gave no time to escape. It is to be proved whether an earthquake preceeded the slide or not? What did the dogs then sense? If they can really sense the slides their faculties can be used to the common good of the humanity.

Acknowledgements

Financial support for the study was made by Department of Science and Technology, Government of India (Grant No. HR/OY/A-23/96) under SERCYS scheme for Young Scientists, while Wadia Institute of Himalayan Geology (WIHG), Dehradun provided the infrastructural support. Drs. V. C. Thakur and R. K. Pant of WIHG, R. C. Lakhera of Indian Institute of Remote Sensing, Dehradun and Navin Juyal of Physical Research Laboratory, Ahmedabad are thanked for valuable discussions and suggestions during the course of the study.

References

[1] J. D. Ives and B. Messerli, *The Himalayan Dilemma* (Routledge, London and New York, 1989).

[2] Economic and Social Commission for Asia and Pacific (ESCAP), *Environmental management of mountain ecosystems in Asia and the Pacific* (Bankok, Thailand, ESCAP, 1989).

[3] O. N. Dhar, A. K. Kulkarni and P. R. Rakhecha, "Meterology of heavy rainfall over Garhwal Kumaun regions of the Himalayas: A brief appraisal", *Proceedings of Workshop on Flood Estimation in Himalayan Region* (Central Board of Irrigation and Power, New Delhi, 1986).

[4] K. S. Valdiya, N. S. Virdi, G. S. Mehrotra, S. Bose and G. Kumar, "Aspects of landslides in UP hills: Remedial measures, public policy and legislative actions", *Subcommittee Report submitted to the Hill Development Department of Uttar Pradesh Government* (1984).

[5] K. S. Valdiya, "Catastrophic landslides in Uttaranchal, Central Himalaya", *J. Geol. Soc. India* **52**, 483 – 486 (1998).

[6] S. K. Paul and A. K. Mahajan, "Malpa rockfall disaster, Kali valley, Kumaun Himalaya", *Current Science* **76**, 485 – 487 (1999).

[7] K. Johnson, E. A. Olson and S. Manandhar, "Environmental knowledge and response to natural hazards in mountainous Nepal", *Mountain Research and Development* **2**, 175 – 188 (1982).

[8] M. Sumitra Gurung, "Beyond the myth of eco-crisis in Nepal: local response to pressure on land in the middle hills", *Unpublished Ph.D. Thesis* (University of Hawaii, Honolulu, 1988).