Ground subsidence: a silent disaster in Himalaya

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Ground subsidence: a silent disaster in Himalaya

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Abstract

Purpose - It is observed that the slow onslaught disasters do not normally catch media attention as these often do not result in human casualties. Inadequate media attention results in insufficient rehabilitation support for the victims. The paper aims at highlighting the problem of ground subsidence in the Himalayan terrain together with the hardships of the victims.

Design/methodology/approach - The paper is based on the detailed field investigations carried out by the author in the remote Himalayan habitations of Garbyang in Dharchula block of Pithoragarh, Tallah Dhumar and Uitti-Bhandragura in Munsiyari block of Pithoragarh and Bagi in Uttarkashi district in the state of Utaranchal in India. All these habitations are being affected by ground subsidence and the inhabitants of these villages are facing severe resource crisis.

Findings - Garbyang village in Central Himalaya is observed to be situated over the varve deposits laid down in the proglacial lake abutting against Chaillekh ridge and is witnessing the problem of ground subsidence resulting in the destruction of the once thriving and prosperous habitation. The studies relate the subsidence at Garbyang with the seismicity in the region as also the subsequent toe erosion and downslope mass movement. The other sites discussed in the paper are witnessing the problem of ground subsidence due to the active toe erosion by rivers and streams.

Research limitations/implications - There exist no records of the exact date of initiation of the ground subsidence in the investigated areas and these are grossly based on the information provided by the village elders.

Originality/value - The article would help in making the disaster managers responsive to the problems the masses are facing due to ground subsidence in this fragile zone and this would result in mustering resources for reducing the hardships of the masses.

Keywords Natural disasters, General management, India, Nepal

Paper type Research paper

Introduction

The Himalayan orogenic belt is the result of the ongoing northnortheasterly drift of the Indian landmass, its subduction below the Eurasian landmass and eventual collision of the alien landmasses resulted in the geological upheaval forming Himalayan mountain belt. Geological evolutionary history has rendered the terrain highly metamorphosed, thrusted, faulted and folded that is reflected in the rocks of the terrain that are highly sheared, fractured, jointed and consequently weak and prone to erosion. High relative relief, extremes of precipitation and high slope gradient, together with the ongoing tectonism further make the terrain highly vulnerable to natural hazards. Normal life in the region is often disrupted by earthquake, landslide, and flash...
flood (1991 Uttarkashi Earthquake, 1999 Chamoli Earthquake, 1998 Malpa landslide, 1998 Okhimath landslide). These major events get their due media attention, which has helped in mustering rehabilitation support from far and wide.

Media attention is, however, a function of human lives lost (that signifies sensation) in the disaster event and it often helps in building pressure on authorities for prompt and adequate relief and rehabilitation support for the disaster victims. It is the media that often highlights the specific needs and problems of the victims and helps the administration and support agencies in mustering appropriate relief material. Many significant events that cause hardships to the masses are, however, often not reported by the media because these events are located in the remote, inaccessible localities and do not have significant human losses. The tendency of weighing the events by the yardstick of lives lost results in non-mustering of the adequate and timely relief and rehabilitation support.

It is a common observation that most slow onslaught disasters pass unnoticed by the media even though these cause heavy and long-term disruption of livelihoods and economy. The relatively slow nature of these events together with adequate response time that these provide result in these events being relatively non-sensational.

Ground subsidence, that adversely affects the livelihood strategy of the masses, is one such disaster that is observed to be frequent in the Himalayan terrain. The residential and other structures are rendered unsafe for human habitation and the masses are forced to face the vagaries of nature, while the agricultural terraces developed over generations and the sole livelihood support asset of most people are lost due to the differential ground movement. This also causes disruption of water seepages and agricultural canals. The forest land is often disrupted leading to loss of common property resources and adversely affecting the livelihood strategy. The ground subsidence thus has adverse impact on the entire livelihood strategy of the masses.

Ground subsidence is observed in the region at a number of places and it is disrupting the livelihood strategy of the masses. The lack of sudden destruction as is the case with other disasters, however, makes it pass unnoticed. It is noticed that even major events taking toll of hitherto populated areas are going on unnoticed by the media. This has resulted in inadequate rehabilitation support for the affected masses that has added to their hardships.

This communication is an attempt to highlight this problem through case studies from the remote Himalayan villages in Pithoragarh and Uttarkashi districts of the Himalayan state of Uttarakhand in India. The locations discussed in the present communication include Garbyang, Talla Dhumar and Umri-Bhandaraiganj in Pithoragarh district and Bagi in Uttarkashi district of the state of Uttarakhand.

The sinking village of Garbyang
The village of Garbyang which has witnessed the problem of ground subsidence for a long time, is situated on the Indo-Nepal border at a distance of 25 km from the road head at Dharchula on the right bank of river Kali in Pithoragarh district of Uttarakhand and has a population of 210 (119 males and 91 females). The village once occupied vast expanse of flat ground overlooking the river. The lacustrine deposits forming a flat ground at Garbyang provided a vintage point to the people whose economic activity thrived on flourishing trade with Tibet supported by a strong backing of livestock. Atkinson (1882) provides vivid account of the multi-storied buildings at Garbyang.
This region was at that time one of the most prosperous tracts of the entire Kumaun region and the economy of the region was intricately interwoven with the migratory traders of the region. Importance of trade with Tibet can well be assessed from the fact that Kasdeashadhipati (king of Kasde; the land of Kasas — the local inhabitants of the region) Baz bahadur Chand (1638-1678) personally supervised the construction of the trade route (Atkinson, 1882).

The surface is presently broken into undulating terraces. Once prosperous village having multi-storied houses with ornate woodwork now lies in a dilapidated state. The yielding ground has taken toll of the houses (Plates 1 and 2) and many have been consumed by sinking ground (Plate 3) and hitherto adjacent ones appear at different levels (Plate 4). Villagers have moved out to nearby safe grounds and most of the exquisitely carved wooden panels have found their way across the Kali in the Nepalese territory. The administration has done little to restore the village and has devised an easy alternative of relocating the people in far off plains that amounts to the alienation of a culture. This approach is not new; these people, basically traders, were previously granted tribal status on the disruption of Tibetan trade following the Sino-Indian border dispute as a poor substitute for their economic loss. It is informed that the ground sinking was out vocally observed sometime after the disruption of the Tibetan trade.

Geomorphology and geology of the Garbyang basin

Garbyang basin is a NE-SW trending valley with flight of terraces cut on lacustrine sediments. The village is located towards the northern flank of the basin and river Kali drains parallel to the southern flank of the mountain. The steep mountain running parallel to the village in the north acts as eyebrow and protects the village from natural hazards. Being a north-facing slope, high rates of evapotranspiration result in little vegetal growth.

Chialekh (lekh means pass in local parlance) is the highest elevation (~3,500 m) towards the west and acts as a major divide separating the lower Kali basin in the west from the higher basin towards the east. The lake sediments (varves) start appearing just below the Chialekh and continue E-NE till Gunji for a distance of 11 km. The relict varve deposits are presently terraced and these run parallel to the valley. The morphology of the terraces suggests these to be tectonogenic with sharp vertical breaks. The degree of preservation is good towards the west while towards the central part and in the east these merge together. The central part of the terraces is undergoing extensive slumping. The axes of slumping coincides with the concavity of the Kali meander that has been pushed towards the north by colluvial debris descending from the southern mountain range along an avalanche chute. River Kali after meeting the Tinkar flows westward on a nearly flat surface, which after draining through the basin makes its exit through a narrow outlet just below the Chialekh.

Unlike most Himalayan rivers which normally follow the strike of the country rocks, Kali cuts across the strike like an antecedent river system. Lithological control on the drainage pattern does not appear to be very striking, on the contrary, the structural configuration seems to dominate the drainage basin.

Tethyan Fault, along which the high-grade Central Crystalline rocks are juxtaposed against the Tethyan sediments to the north, expresses itself geomorphologically by prominent ridges. Chialekh ridge in the Kali valley is the surface expressions of this...
Plate 1.
View of the ornate house devastated by ground subsidence at Garbyang village in the Kali valley.

Plate 2.
View of the house deformed by ground subsidence at Garbyang village in the Kali valley.
Ground subsidence: a silent disaster

Plate 3.
The ground floor of the house has been consumed by the sinking ground at Garbyang village in the Kali valley. The wooden frame of the ground floor door is visible at the bottom.

Plate 4.
Houses that once were adjacent appear at different levels across a fault scarp running E-W at Garbyang village in the Kali valley.
tectonic plane. This ridge defined the distal end of the palaeolake at Garbyang in which was laid down a continuous sedimentary record.

**Deformational features around Garbyang**

Four distinct episodes of tectonic disturbances are observed in the varve succession at Garbyang and these are attributed to past seismicity in the region. The fault planes in all the four deformational events show similar spatial orientations, which is suggestive of their similar causative force, although separated by considerable time gap. The fault planes dip towards north and south at moderate to high angles. Based on the statistical orientation of these planes palaeostress orientations have been worked out. $\sigma_3$ is observed to be almost vertical while $\sigma_2$ and $\sigma_3$ are almost horizontal which is an ideal state for normal faulting. The sediment mass in the proglacial lake has witnessed gravity induced faulting in response to the tectonic disturbances in the vicinity as many as four times. Proximity to the Tethyan tectonic boundary is suggestive of the seismic activity being related to the movement along this plane.

Deformation in the mass that has already slid down is observed at the right bank of Kali to the south of the in situ section. The mass that has slid down has formed folds that are owed to gravity gliding. Two distinct fold generations are observed in this mass. These are coaxial showing Type III interference pattern of Ramsay (1967) with the fold axes being WNW-ESE-oriented. These folds are the manifestations of the drag along the slide plane. Most folds are recumbent with thinned normal limb.

These deformations are the product of gravity gliding alone; the mass has slid down from N-NE along the weak plane paralleling the valley walls. Such weak planes were also observed in the Garbyang village (Plate 4), where along a E-W-oriented fault plane the sediments have gone down as much as 4 m at the eastern end. The displacement at the western end is however of the order of 20 meters. This plane is observed for 150 m and is associated to the Dharchula earthquake of 1980. Erosive forces have not yet concealed the scrap and the surface is still fresh. No shattering of boulders was, however, observed along this scrap. Houses that were once at one level are now observed at different levels across this fault line.

**Sinking villages of Talla Dhumar and Umli-Bhandarigaon**

Talla Dhumar village (30° 06.490' N, 80° 15.026' E) is situated at a distance of 3 km from the road head on the Munsyari-Madkot-Jauljibi motor road, on the right bank of Goriganga river in Munsyari block of Pithoragarh district and has a population of 265 (120 males and 145 females) while Bhandarigaon (30° 02.056' N, 80° 09.709' E) is situated on the Thal-Munsari motor road near Birthi Fall to the SW of Munsari (30° 03.933' N, 80° 14.161' E) and has a population of 228 (121 males and 107 females).

Both these villages show similar geomorphic set up and are located over vast old rock fall debris evidences of which are clearly observed on the upper slopes of the villages (Plate 5). Soil formation, however, took place on the lower slopes that were modified by fluvial action and the habitation came up over these in due course of time. There exists a steep scarp over the villages and there is a massive waterfall (Birthi Fall) in the scarp over Bhandarigaon. This is suggestive of the presence of a major tectonic boundary in the vicinity. Goriganga is also observed to follow a linear course in the region that also suggests presence of some tectonic discontinuity.
It was in 1995 that the lowermost portion of the stabilised rockfall at Talla Dhumar was subjected to erosion by the Goriganga floods. The untreated scar progressively enhanced by the toe erosion and the percolation of water through the destabilised soil mass facilitated finer particles to be washed off through solution action of the water. Over the years this has resulted in the formation of holes in ground and consequent appearance of boulders over hitherto flat agricultural terraces (Plate 6). With ongoing toe erosion the process of ground subsidence and creep has been initiated on large scale and vast tracts of agricultural land have subsequently been rendered unfit for cultivation. The affect of ground subsidence is also reflected on the residential structures of the village and many of these are partially damaged.

A similar situation is observed at Umli-Bhandarigaon where the toe erosion by Jakula Gad has destabilised the mass and increased seepage of water (due to water harvesting and other work undertaken by Watershed Directorate and the Department of Soil Conservation in recent years) has increased the pace of ground subsidence. Affects of ground subsidence are clearly seen on the residential structures of the village (particularly in the lower reaches) where the agricultural fields are also disrupted by ground subsidence (Plate 7).

**Sinking village of Bagi**

Bagi village is situated on the left bank of the upper catchment of Jalkur river in Uttarkashi district and has a population of 464 (239 males and 225 females). The riverbank below the Bagi village reportedly supported thick forest cover till 1994 when cloudburst in the upper catchments of the river washed off the forest and the slopes became destabilised and invited erosion. At that time due attention was not paid towards undertaking bank stabilisation measures. It is reported that after 1991 Uttarkashi Earthquake (6.1 on Richter scale) transverse cracks encircling the village...
Plate 6.
Holes in the agricultural land at Talla Dhumar village

Plate 7.
House damaged by ground subsidence at Bhandariangan village
from three sides appeared in the ground surface on the slopes above Bagi village. Continued weathering along these fractures and percolation of rainwater along these prepared stage for a major tragedy at this place.

It was during the monsoons of 1998 that the whole of the mountain slope was dislodged along these pre-existing fractures. Though the loss of human lives was averted as the event took place during broad daylight and was slow. Most houses were however destroyed and the terraced land was rendered unfit for cultivation (Plate 8). This tragedy was overshadowed by major tragedies that took place almost simultaneously at Okhimath and Malpa and did not make news headlines. The masses therefore did not receive adequate relief and rehabilitation support.

Even after more than six years of the tragedy the wide-open fractures encircling the village are clearly visible on the ground surface (Plate 9) and displacement of the order of 15 m is observed across these. At the eastern end of the village the slip surface is North-South-oriented (striking N 165°-N 345°) and the western side has been downthrown by 5.5 m. On the higher reaches of the village the fracture plane is observed to be Northeast-Southwest-oriented (striking N 60°-N 240°) and the down-throw is of the order of 15-20 m. At the southeastern extremity of the village the fracture plane acquires almost East-West orientation (striking N 100°-N 280°). These observations show that the fracture encircles the village and the toe erosion at the base is causing down slope movement and consequent subsidence of the ground.

Almost all the agricultural terraces developed over generations have been rendered unsuitable for cultivation. Left with no other alternative life support strategy the masses are indiscriminately re-terracing these slopes which might invite yet another devastation. Continued toe erosion by the river is activating the destabilisation and the agricultural activity is leading to a complication of the problem. Furrowing and stagnating water are, however, detrimental to the stability of these slopes. The
blockade of the stream course by the debris that has slid down has the potential of threatening the downstream habitations.

**Discussion**

The fault observed in the *in situ* varve deposits at Garbyang is, however, the manifestation of the palaeoseismicity in the region related with the movement along the Tethyan Fault that forms the distal boundary of the proglacial lake. The absence of liquefaction features that are commonly cited as evidence of past earthquakes is attributed to the absence of sandy horizons in the varve succession, as it is the increased pore water pressure associated with the liquefaction of sand rich layers that causes these features (Obermeier, 1996). The region is tectonically active and has experienced many earthquakes in the past (Paul, 1986, Srivastava *et al.*, 1986). These disturbances are observed to be confined to the lower part of the profile followed by a long phase of quiescence.

The subsidence of the ground surface at Garbyang is, however, caused by the toe erosion by river Kali and consequent down slope movement. The mass is moving under gravity along the pre-existing tectonogenic weak planes. The toe erosion by Kali is accelerating the pace of movement and ground subsidence.

The central part of the Garbyang basin that houses the Garbyang village is undergoing severe land subsidence. Currently, the village is undergoing serious land degradation amounting to total and near partial damage of the houses. According to the villagers there were four streets in the village (situated at Terrace 1) that were parallel to the terrace i.e. E-W trending. Today there exist virtually no streets and there are only a few houses left on Terrace 1. All the streets have merged together resembling a shamble of houses put together in a basket. Except for the few houses on Terrace 1, which is very close to the mountain and is protected from the north by the calc-silicate ridge, all other terraces in the central part have been merged together due
to the continuous land movement, although the downward movement accompanied by vertical subsidence varies from locality to locality in the village. A maximum of around 20 m of displacement is deciphered in houses where the old reference surfaces are available. The development of fissures, cracks, distortion and buckling in the houses is the adjustment of the near rigid structure of the buildings due to the stresses developed because of the yielding earth beneath them.

The Kali river which flows E-W is constantly eroding the varve deposits from the base and thus the mass from the north is moving down along pre-existing seismogenic weak planes. This movement expresses itself in the folding of the sediments and is threatening the very existence of Garbyang village.

At all the other places, i.e. Umli-Bhandarigaon, Talla Dhumar and Bagi toe erosion by the stream draining through the base of the old stabilised landslide mass has caused its reactivation and the slip surfaces are observed to parallel the course of the streams. Percolation of water through the destabilised mass and downslope creep is reflected in the subsidence of the ground surface and threatens the life support strategy of the masses.

Recommendations
For restoring the landscape of the villages studied and for saving the cultural roots of the people the following measures are suggested:

- Debris from the southern slope across Kali may further aggravate the pace of toe erosion and therefore a series of wire mesh retention walls are required to be erected along this slope.
- The right bank of Kali along the concave meander, together with the right bank of Jakula Gad below Umli-Bhandarigaon, right bank of Goriganga downslope of Talla Dhumar and left bank of Jalkur Gad below Bagi need embankment and other protective measures.
- Plantation along the course of the streams would be helpful in slope stabilisation.
- The middle slopes at all the places are observed to be showing out vocal sighs of subsidence and have been gullied. These need terracing to reduce the pace of mass wastage.
- Lightweight houses in these areas would relieve pressure and reduce forces causing downslope movement.
- Avoidance is the best strategy for any slide prone area and therefore is required that all kind of anthropogenic activity is discontinued in the zones showing active subsidence. This would provide opportunity for the natural regenerative processes to stabilise the area.
- Provision of diversion of water from the head of the slide through diversion channels is a must. These channels would discourage water from entering the fracture planes and the pace of weathering would be slowed down drastically and this would give natural forces time to heal the crack.
- In order to make the restoration work acceptable, successful and cost-effective people’s participation must be ensured.
Non-land-based economic activities need promotion in the villages so that the villagers are encouraged to allow restoration work to be carried out in their fields.

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