

## Assessment of the valley-blocking ‘So Bhir’ landslide near Mantam village, North Sikkim, India, using satellite images

A massive landslide occurred near Mantam village (opposite the Passingdang–Mantam Road) in Sikkim, India around 13:30 h (IST) on 13 August 2016 (Figure 1 *a*). The location (at the centre of the zone of depletion) of the landslide was 27°32′22.92″N and 88°30′2.47″E. According to the news reports, formation of a lake and consequent rise in water level had submerged the bridge over Kanaka river and washed away about 300 m stretch of the road. Five houses in Mantam village were also submerged. The villages of Tingvong, Lingdem, Laven, Kayeem, Lingzya, Bay, Sakyong Pentong and Ruklu Kayeem were cut-off due to damage to the connecting road. However, there were no human deaths reported due to the incident.

The landslide generated a huge cloud of dust engulfing nearby settlements (Figure 1 *b*). From the field photograph it appears to be a rock avalanche and the dust cloud was formed due to rapid down-slope movement of dry rock mass resulting in an air-blast. The debris from the landslide has blocked the flow of the Kanaka river/Tolung Chu, which is one of the main tributaries of the Teesta river.

Remote sensing data have proved useful for rapid assessment of landslides and landslide dammed lakes<sup>1–4</sup>. An analysis was carried using very high resolution Cartosat-2B (~80 cm spatial resolution) image acquired on 15 August 2016. The

width of the landslide was 530 m in the middle and length 790 m. The landslide was rectangular and the crown was located on a ridge line (Figure 2). Debris deposits can be clearly observed on either side of the ridge line. Joints exposed after the landsliding suggest a wedge type of failure near the crown followed by translational type of failure in the main body of the landslide. The water impoundment caused by the debris deposited on the river valley had resulted in the formation of an artificial lake of 2.2 km length and 209 m width at the lake head (Figure 1 *c*). The lake engulfed a total area of 110,245 m<sup>2</sup>, upstream of the river, along the valley.

Geologically, the area is in proximity with the Main Central Thrust (MCT), which is convex to the north and forms a tectonic window known as Rangit window<sup>5,6</sup>. Due to MCT, high-grade rocks of Proterozoic Central Crystalline Gneissic Complex (e.g. quartzites, schists and granite gneisses) are exposed in this area. These rocks were subjected to shearing which is evident from the density of joints in the landslide scarp region. Area around Sakkyong in the upstream part of Kanaka river also witnessed severe landslide occurrences during the Sikkim earthquake on 18 September 2011 (refs 4, 7). Groundwater seepages from the exposed joint planes are clearly visible in the Cartosat-2B image (Figure 2). Therefore, the aquifer-induced pore pressure

(due to earlier monsoon rains) and escarpment stress condition, as evident from the presence of an old landslide, could be the probable causes of landslide occurrence on 13 August 2016.

Landslide resulting in river blockage presents a serious threat to downstream settlements. In recent times, we have recorded two large events of valley-blocking landslides in the Himalaya. The August 2014 Sunkoshi landslide<sup>8</sup> resulted in a ~2 km long lake on the Sunkoshi river, which is one of the main tributaries of the Kosi River as it enters India. This has led to large-scale human evacuation in Bihar. Similarly, the Phuktal river landslide<sup>9</sup> in Jammu and Kashmir, India resulted in the formation of a ~17 km long lake which needed regular monitoring to avoid major flash floods in the downstream areas. The water impoundment in case of the ‘So Bhir’ landslide is a potential threat to settlements in downstream areas and to the Teesta Stage-V project of National Hydroelectric Power Corporation (NHPC). We estimated the volume of lake water from a 10 m CartoDEM using the polygon volume method. The water volume was estimated as 2.16 million m<sup>3</sup> and assuming that the lake would be emptied in 30 min in case of a sudden breach, the discharge was estimated at 1202 m<sup>3</sup>/s. For this amount of discharge, we carried out a risk analysis for possible inundation due to flash floods for a distance of



**Figure 1.** Photographs of (*a*) the Mantam landslide, (*b*) dust cloud from the landslide, (*c*) artificial lake formed due to the landslide dam (Source: savethehills.blogspot.com).

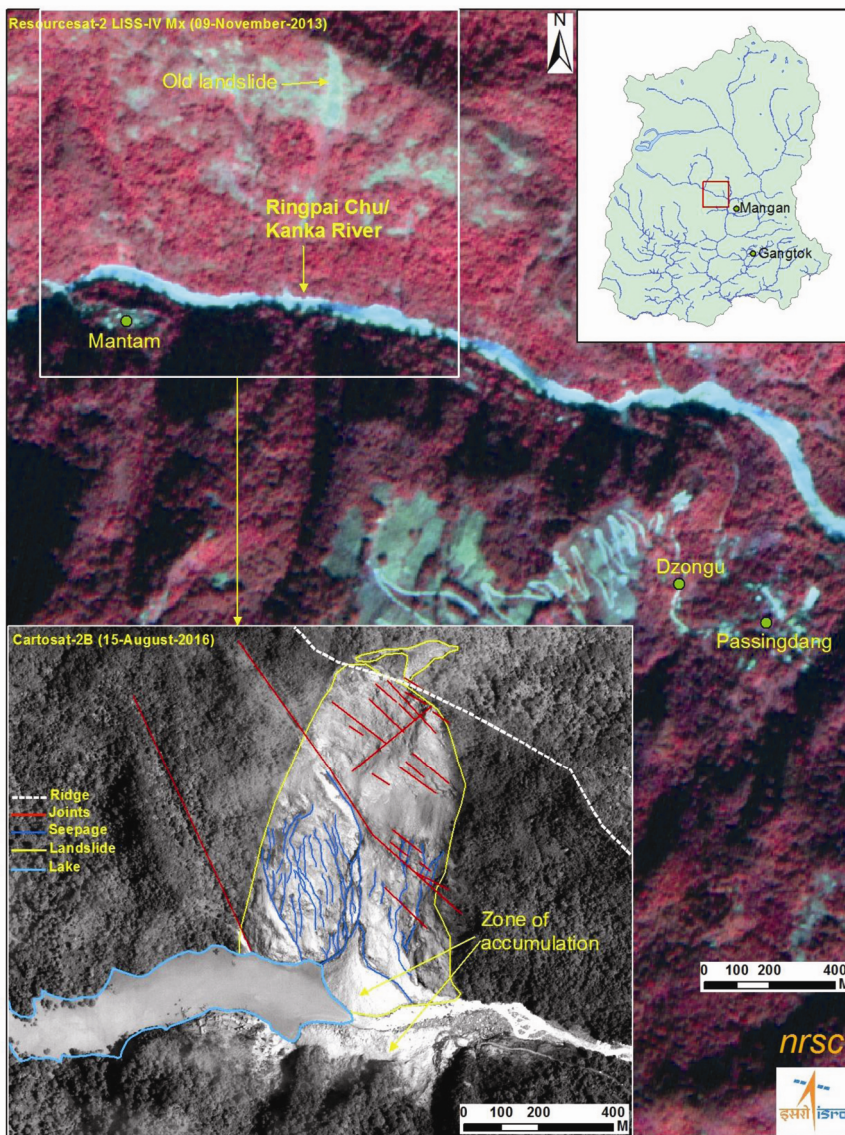


Figure 2. Analysis of 'So Bhir' landslide using Cartosat-2B image.

15 km in downstream areas. No major settlements were found in the vicinity of the river within this distance which would be affected due to a potential flash

flood. However, as seen from the Cartosat 2B image, the river has overtopped the debris dam and is now flowing along its natural course in the form of a turbu-

lent rapid. As a consequence, the lake water is draining out through the narrow outlet.

1. Mantovani, F., Soeters, R. and van Westen, C. J., *Geomorphology*, 1996, **15**(3–4), 213–225.
2. Huang, R. and Fan, X., *Nature Geosci.*, 2013, **6**, 325–326.
3. Martha, T. R., Roy, P., Mazumdar, R., Govindharaj, K. B. and Vinod Kumar, K., *Landslides*, 2017, **14**(2), 697–704.
4. Martha, T. R., Govindharaj, K. B. and Vinod Kumar, K., *Geosci. Front.*, 2015, **6**, 793–805.
5. GSI, *Seismotectonic Atlas of India*, 2000.
6. Ravi Kumar, M., Hazarika, P., Srihari Prasad, G., Singh, A. and Saha, S., *Curr. Sci.*, 2012, **102**, 788–792
7. Ghosh, S., Chakraborty, I., Bhattacharya, D., Bora, A. and Kumar, A., *Indian J. Geosci.*, 2012, **66**, 27–38.
8. Roy, P., Martha, T. R. and Vinod Kumar, K., *Curr. Sci.*, 2014, **107**(12), 1961–1964.
9. Martha, T. R. *et al.*, *Landslides*, 2017, **14**(1), 373–383.

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