Landslide delineation from space-borne radar data – issues and limitation

On 18 September 2011, an earthquake of magnitude 6.96 on the Richter scale occurred in the northeastern part of India with its epicentre located near the Kanchenjunga conservation area. The epicentre of the earthquake was also located 68 km northwest of Gangtok, the capital of Sikkim[1] and thus had the greatest impact on Sikkim and its surrounding areas. Mangan and Chungthang in the North Sikkim District were the worst affected due to this earthquake (Figure 1). Most of the damages during the earthquake was compounded by the landslides. In an attempt to delineate the landslides and related damages, multispectral, high-resolution panchromatic data-acquiring satellites and microwave satellites were programmed to collect data over the epicentre and adjacent areas. Due to cloud cover, the multispectral data could not be used for damage assessment. However, Cartosat-1 data were acquired for few cloudless windows. Post-earthquake Radarsat-2 data were also analysed for these windows for understanding the potential of the radar data in damage assessment in comparison to the IRS P5-Cartosat-1 data. Pre-event IRS (Indian remote sensing satellite) P6 LISS-IV, IRS P5 cartosat-1 data were used in conjunction with the post-event Radarsat-2 data and Cartosat-1 data to delineate the earthquake-induced landslides and the associated damages.

In this context it is important to mention that satellite remote sensing has played a significant role in mapping the landslides, and satellite data from different sensors have been used for this[2,3]. It has been observed that the earthquakes often trigger landslides in mountainous terrain[4–6]. Satellite pictures are routinely used to assess the post-earthquake damages. But the availability of cloud-free images from optical sensors for the disaster-prone areas is always an issue. Radar data, due to their cloud penetration capability, have a better capability to view the terrain in spite of the cloud cover. But the application of radar data in mapping the landslides and associated damages is limited in the rugged terrain.

In the present study, the capability of radar data in delineating post-earthquake landslides is examined. Most of the areas at northeastern Himalayas are often covered under cloud, especially during the monsoon period (July–September). In such a condition, radar data are the logical alternative for carrying out damage assessment. In radar remote sensing, surface roughness and dielectric constant are the two major geophysical properties of the terrain surface that govern the backscattering return of the radar signal, and these are to be considered as important factors for landslide mapping. In addition to above, look angle and look direction of radar antenna with respect to the slope and regional topographic trend of the terrain also contribute in subduing or enhancing terrain features like landslides in the radar images.

In the present study, Radarsat-2 data acquired within 24 h of the earthquake were used. The data were compared with the pre-event IRS P 5 Cartosat-1 data and IRS P6 LISS IV data of the same area (Table 1). The analysis of Radarsat-2 data (post-event) could not delineate any earthquake-triggered landslides, but these landslides are well-delineated in the post-earthquake Cartosat-1 data. The relationship between dip directions of the hill slope with respect to the look direction

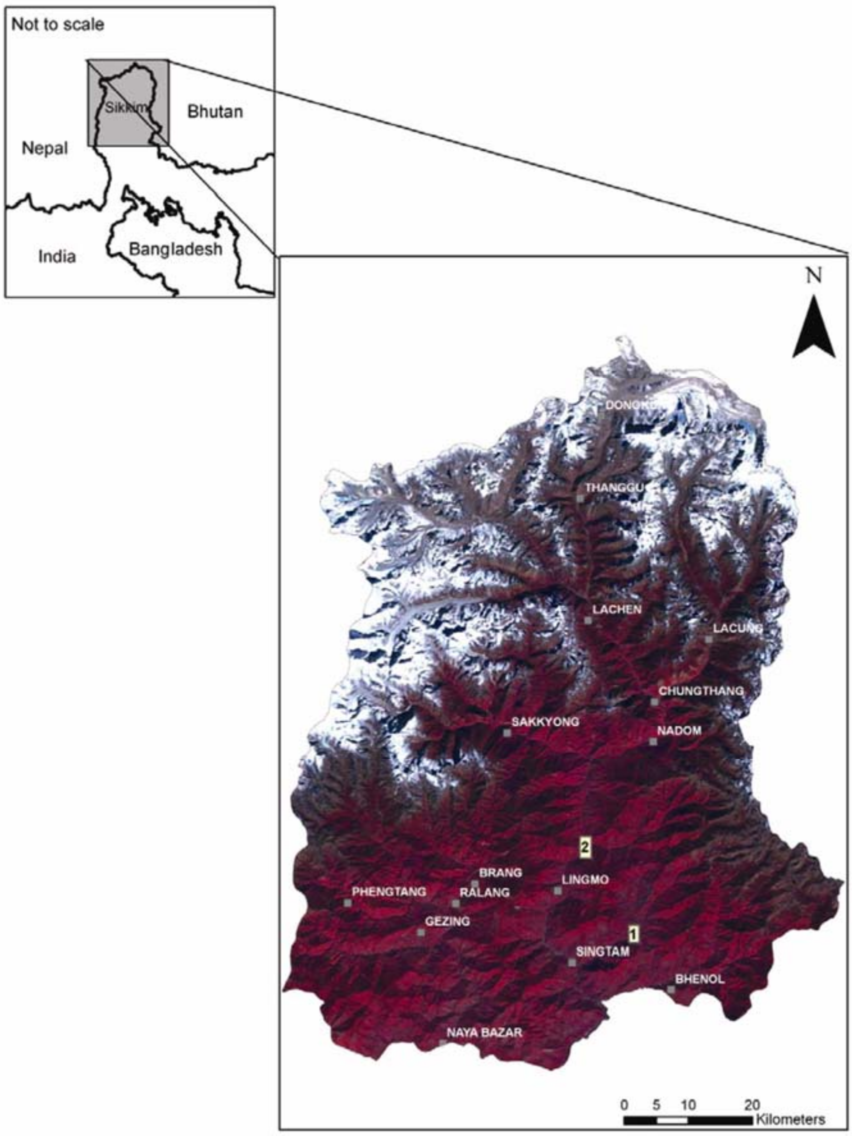

Figure 1. Study area (1, study area analysed in Figure 2; 2, study area analysed in Figure 3).

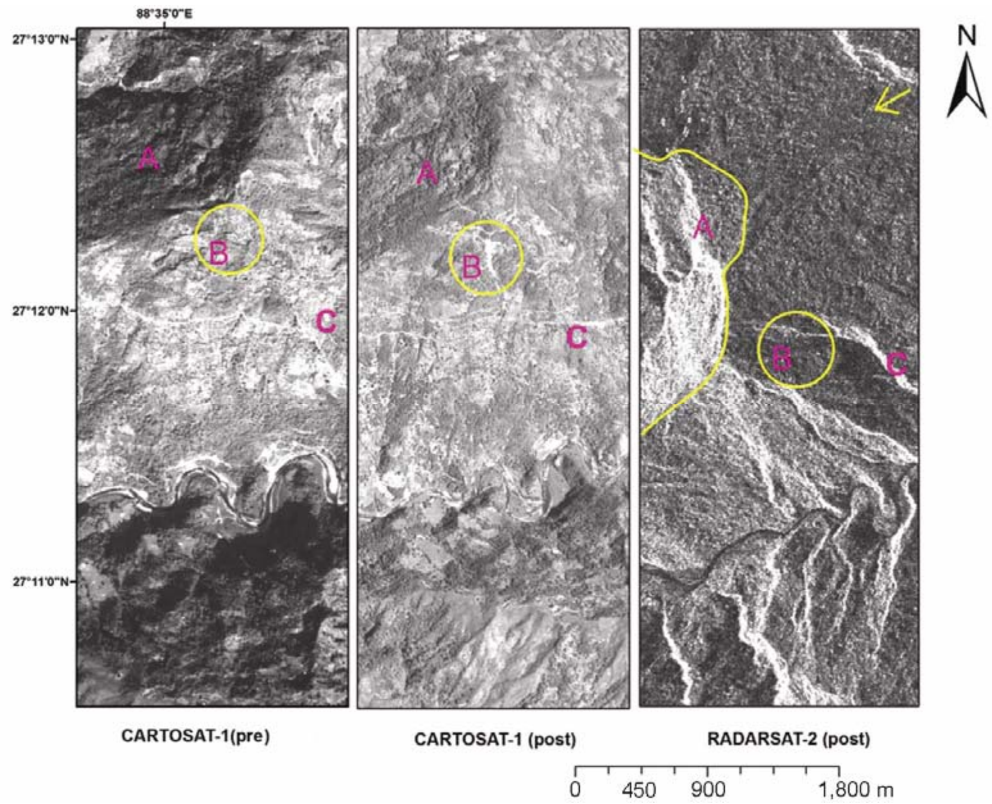

Figure 2. Radarsat-2 data with the look direction from NE–SW subdue the landslide impression on the slope trending approximately in the NE–SW direction. The slope (A) is partly subdued in the radar image; slope (C) is enhanced in the radar image. Landslide (B) is also subdued in the radar image. Look direction of radar acquisition is shown with an arrow in the radar image.

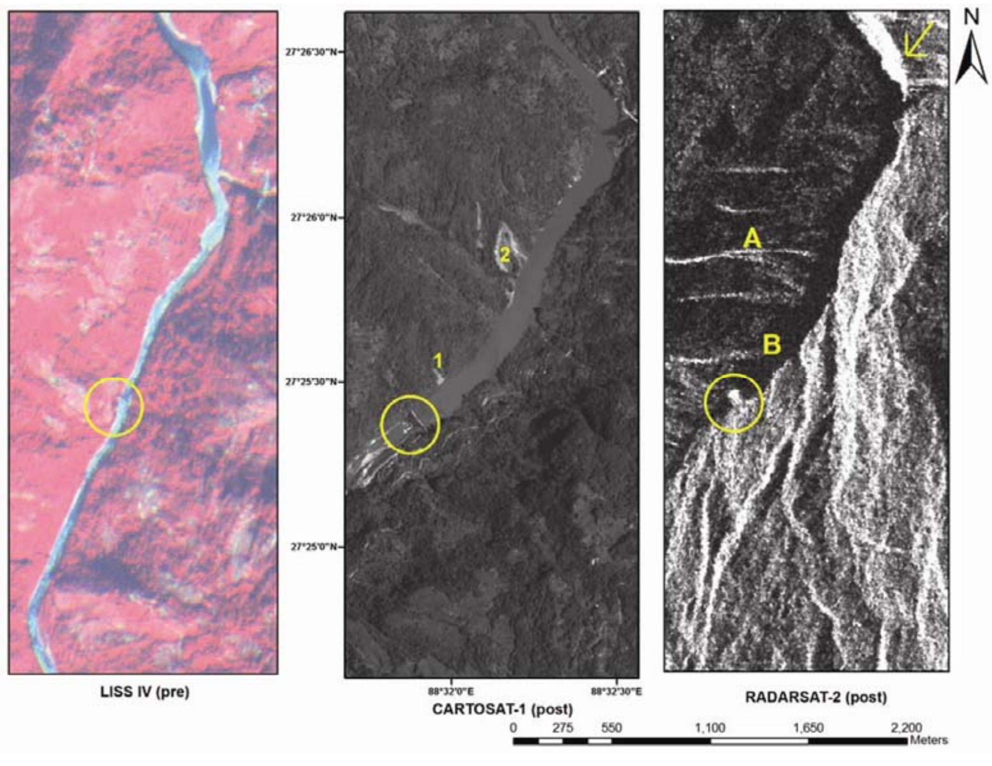

Figure 3. Landslides are marked as 1 and 2 in the post-earthquake Cartosat-1 data. They are not delineated in the Radarsat-2 data. Some slopes (A) are enhanced, while a few slopes (B) are suppressed. Look direction is shown with an arrow in the radar image. A dam is shown with circle in post-Cartosat-1 and Radarsat-2 data.

Table 1. Details of the data used in the present study

Country	Sensor type	Sensor name	Specifications	Date of acquisition	Remarks
India	Optical	IRS P6 -LISS IV	23.5 m, 140 km Swath	21-11-2008	Pre-event
India	Optical	Cartosat-1	2.5 m, 26 km Swath,	11-11-2008	Pre-event
India	Optical	Cartosat-1	2.5 m, 26 km Swath,	30-09-2011	Post-event
India	Optical	Cartosat-1	2.5 m, 26 km Swath,	11-10-2011	Post-event
Canada	Microwave	Radarsat-2	Multilook fine beam, HV polarization, 8 m ground resolution, operative in C band (average wavelength 5.6 cm)	19-09-2011	Post-event

of the radar antenna is a sensitive criterion; which contributes in enhancing or subduing the slope feature. It has been observed that the hills slopes, which are either parallel to or at low angle (marked as A in pre-event and post-event Cartosat 1 data) with the look direction of radar acquisition are subdued in the radar image and this also contributes in suppressing the landslides (if landslides occur in this slope) from the radar data (Figure 2). Terrain slopes with their orientation perpendicular (marked as C in the radar data in Figure 2) to the look direction of radar acquisition and slope angle equal to the look angle of the radar beam will produce bright and linear return. In these slopes, delineation of the landslides would be difficult. In the radar image (Radarsat-2 data), landslide is subdued (marked as B) which is clearly visible in the post-earthquake Cartosat-1 data (demarcated as B within the circle in Figure 2). Landslide, in this case, has not been delineated as the slide area may not be delineated based on the roughness and dielectric constant from the adjacent terrain using C-band microwave signal. In another instance, it has been observed that the earthquake-induced landslides are delineated in Cartosat 1 data (landslides are marked as 1 and 2 in Figure 3), whereas these landslides are not delineated in the post-earthquake Radarsat-2 data. These landslides were induced during the earthquake as the pre-event IRS P6 LISS IV data could not detect them. The look direction of the radar antenna is along the NE–SW direction and therefore NW–SE trending or WNW–ESE trending slopes (marked as A in Figure 3) contribute higher backscatter return in the radar image. On the other hand, N–S or NE–SW trending (marked as B in Figure 3) slopes are subdued. Therefore, the landslides occurring in the NE–SW trending slopes (marked as 1, 2 in radar image in Figure 3) also remain suppressed. In summary, the look direction of the radar image and its relationship with the trend of the hill slope are important governing factors in addition to the roughness and dielectric constant of the landslides for delineating landslides in the radar images. Landslide features often have surface roughness coarser than the wavelength of the C band (wavelength of the radar signal used for imaging) and this roughness is comparable with the roughness of other terrain elements. Therefore, it would remain suppressed in radar image.

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