Drivers for the development of an alluvial fan in a high-altitude glaciated catchment

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Background

The Langtang valley, ~60 km north of Kathmandu is one of the most intensely researched catchments in the Nepalese Himalayas. Already in the 1950s first investigations were carried out in a small proglacial valley found to be the site of a massive landslide that occurred 10^4 years ago. The displaced mass encompassed 10–15 billion m^3 and is possibly the largest terrestrial land movement in a crystaline environment (*Figure 1*). The failure likely happened due to a sulfidic mineralized ore structure within a discordant leucogranitic dike that slipped during an earthquake related to the Main Central Thrust (MCT) [*Ibetsberger 1996, Weidinger et al. 1996, Schramm et al. 1998*].

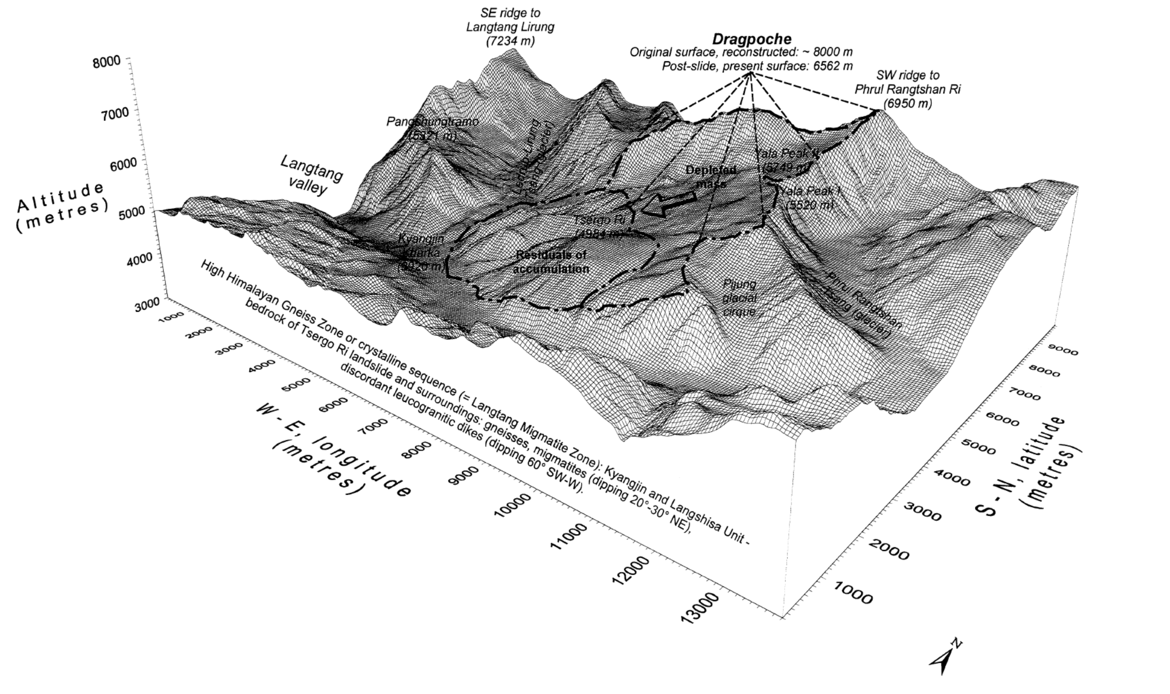

Figure 1: The Tsergo Ri landslide extent possible displaced landmass (taken from Weidinger et al. (2002))

The upstream area of the failure is today covered by a clean-ice glacier (Yala Glacier), ranging from 5170 – 5630 m asl. and an area of 1.6 km² [*Ragettli et al. 2015*]. The glacier drains partly towards the Lirung glacier further West but mainly into an incised channel towards the South (Dranglung Chu, *Figure 2 and 3*). Heavy erosion is visible along the valley's flanks since many years and the valley ends in an alluvial fan covering the entire width of that Langtang valley below (*Figure 3*).

Initial Research Questions

While the Geology has been well determined in the specific area also explaining why the landslide occurred in this particular spot and the petrography of the alluvial fan is documented [*Weidinger et al. 2002*] it is not clear how the fan has developed and why it did so increasingly only in recent years. High resolution imagery from November 1974 and October 2015 and evidence from earlier studies in the late 90s suggests it became reactivated in the late 70s during a flash flood [*Schramm et al. 1998*] as new fresh

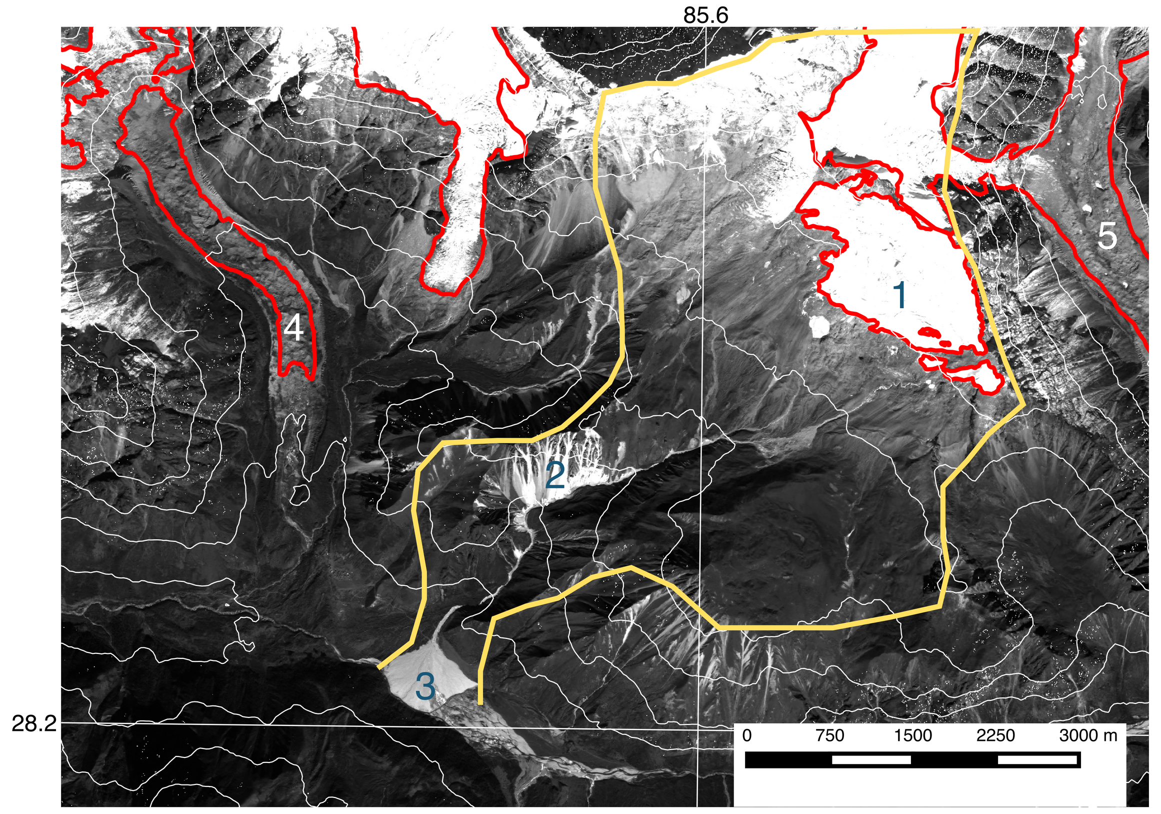

Figure 2: An orthoimage (SPOT6) from the field site (yellow extent showing approximately the extent of the mass movement shown in Figure 1) with Yala glacier (1) on the top right and the likely main debris source area (2) as well as the alluvial fan (3) further south. The debris covered tongue of Lirung glacier (4) is on the left, Shalbacum glacier (5) on the right.

Figure 3: Heavy erosion (top left) in the mid stream of the proglacial valley. The alluvial fan taken from the East (top right) and from below Tsergo Ri (bottom left)

deposits become visible. With the recent earthquake in April 2015 that also heavily affected the Langtang area [*Kargel et al. 2016*] the question arises again whether the growth of this fan is predominately **driven by**

(a) **glacial melt** from the Yala glacier
(b) **precipitation** over the whole year
(c) heavy **monsoon rains**
(d) minor or major **seismic events**

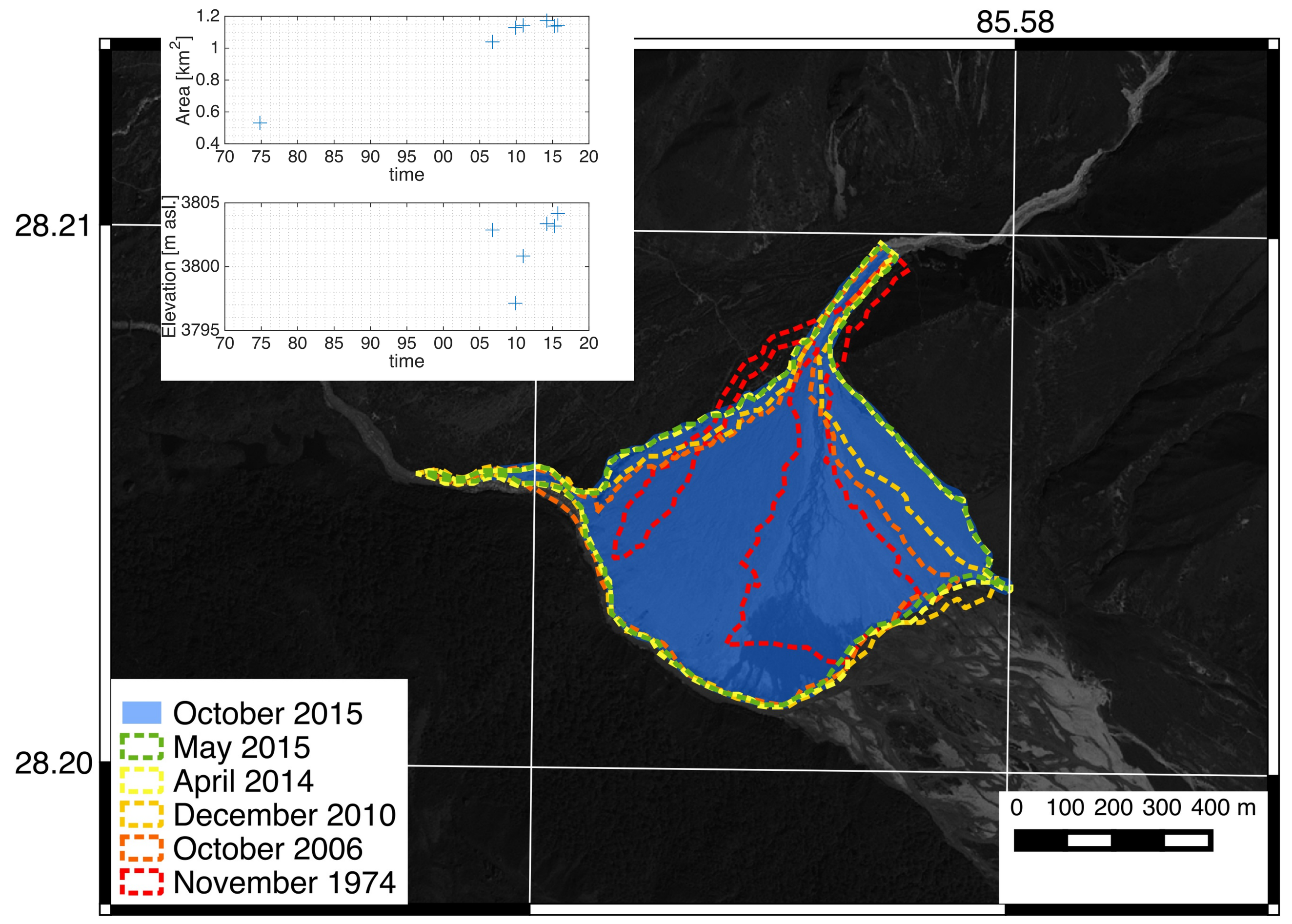

Figure 4: Development of the fan between November 1974 and October 2015. The earthquake occurred in April 2015. Change in area and mean elevation are shown in the inset on the top left.

Results

The alluvial fan has grown significantly since 1974 but there was no significant change after the earthquake in May 2015 or the subsequent monsoon (*Figure 4*). More analysis of higher temporal resolution would be necessary for conclusions on seasonal changes driven by heavy monsoon rains.

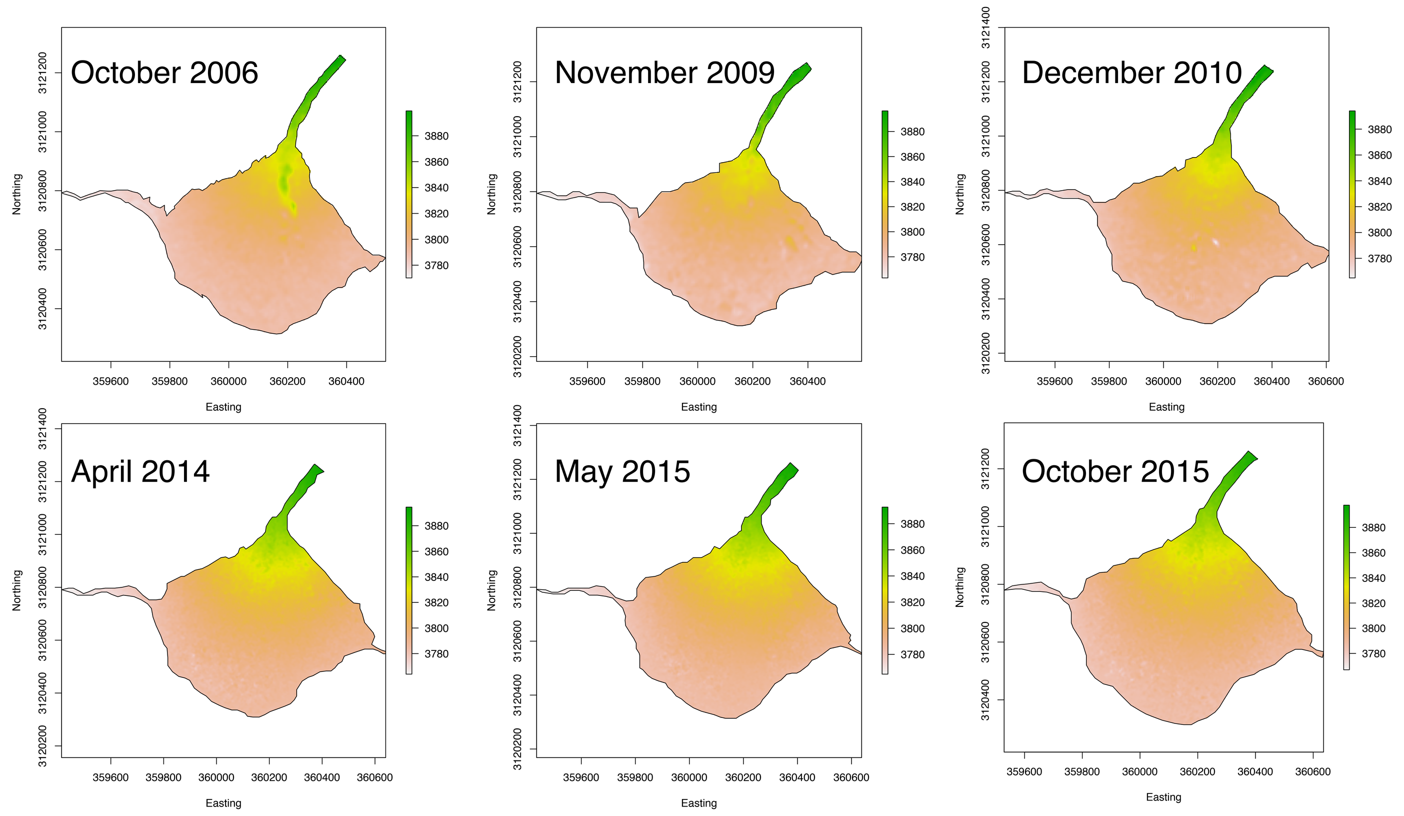

Figure 5: DEMs derived from the fan outlines from 2006 to 2015.

An initial channel at the top of the fan has since levelled out and deposition is relatively homogenous. This could point to few extreme events (*Figure 5*). The area gain per year ranges between 10 000 and 30 000 m² however if recent years are an indicator there is a decrease in area gain combined with a slight increase in deposition height.

Rapid local changes like the gain in area between 2010 and 2014 are obvious however seem to be very heterogeneous in time.

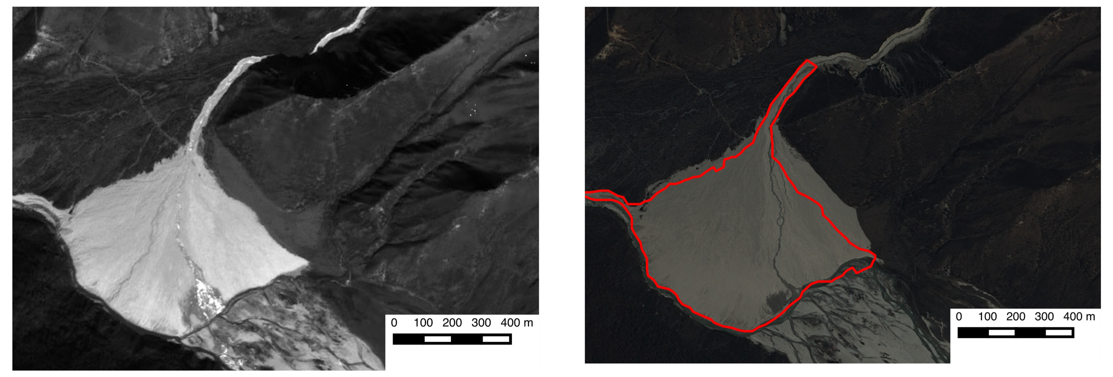

Figure 6: Change in extent of the alluvial fan between Dec 2010 and April 2014. The growth on the top right fringe is apparent.

The small effect by the earthquake is also substantiated by the very minor changes in erosion in the upstream before and after the event. This does also not change after the following Monsoon season (*Figure 7*).

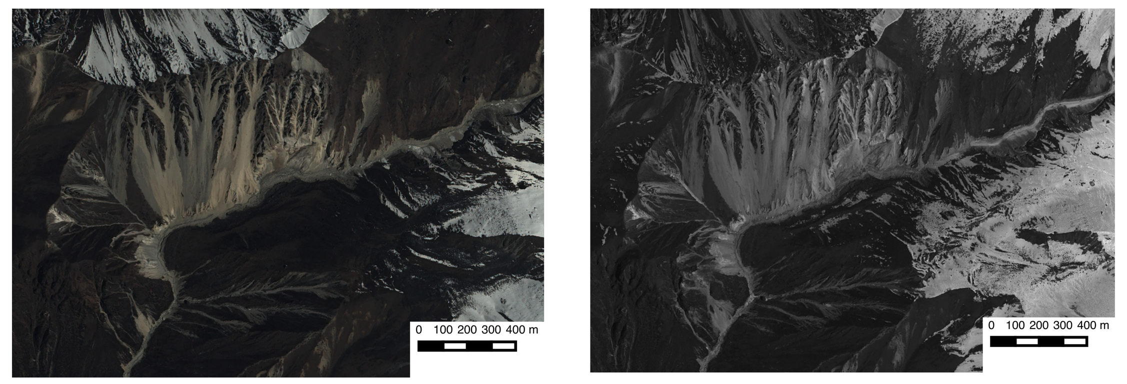

Figure 7: Changes in erosion in the upstream before (left, April 2014) and after (right , May 2015) the earthquake.

Selected Literature

Ibetsberger, H. (1996), **The Tsergo Ri landslide: an uncommon area of high morphological activity in the Langthang valley, Nepal**, Tectonophysics, 260 (1996) 85-93 ; Weidinger, J., Schramm, J., Surenian, R. (1996), **On preparatory causal factors, initiating the prehistoric Tsergo Ri landslide (Langthang Himal, Nepal)**, Tectonophysics 260 (1996) 95-107; Schramm, J., Weidinger, J., Ibetsberger, H. (1998), **Petrologic and structural controls on geomorphology of prehistoric Tsergo Ri slope failure, Langtang Himal, Nepal**, Geomorphology 26 1998. 107–121; Weidinger, J., Schramm, J., Nuschej, F. (2002), **Ore mineralization causing slope failure in a high-altitude mountain crest—on the collapse of an 8000 m peak in Nepal,** Journal of Asian Earth Sciences 21 (2002) 295–306; MacFarlane, A. M. (1993), **CHRONOLOGY OF TECTONIC EVENTS IN THE CRYSTALLINE CORE OF THE HIMALAYA, LANGTANG NATIONAL PARK, CENTRAL NEPAL**; TECTONICS, VOL. 12, NO. 4, PAGES 1004-102; Kargel, J. et al., **Geomorphic and geologic controls of geohazards induced by Nepal's 2015 Gorkha earthquake**, Science VOL 351 ISSUE 6269