



Vulnerability assessment of Glacial Lake Outburst Floods using Remote Sensing and GIS in North Sikkim (India), Eastern Himalaya

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Glacial lake outburst floods (GLOFs) occur when glacier melt water dammed by a moraine is released in short time. Such floods may lead to disastrous events posing, therefore, a huge threat to human lives and infrastructure. A devastating GLOF in Uttarakhand, India, on 17 July 2013 has led to the loss of all villages in a stretch of 18 km downstream the lake and the loss of more than 5000 lives.

The present study evaluates all 16 glacial lakes (with an area $>0.1 \text{ km}^2$) in the Thangu valley, northern Sikkim (India), eastern Himalaya, with respect to potential threats for the downstream areas. The hazard criteria for the study include slope, aspect and distance of the respective parent glacier, change in the lake area, dam characteristics and lake depth. For the most hazardous lakes, the socio-economic conditions in the downstream areas (settlements and infrastructure) are analysed regarding the impact of potential GLOFs.

For the vulnerability analysis, we used various satellite products including LANDSAT, RESOURCESAT-1 and 2, RISAT-1 imageries and ASTER GDEM covering the period from 1977 to 2014. For lake mapping, we applied the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Snow Index (NDSI). A Land Use Land Cover (LULC) map of the study area showing in-situ observations is serving as driving factor for the vulnerability analysis.

The results of the study show that almost all evaluated glacial lakes were expanding during the study period (1977-2014). Combining the hazard criteria for the lakes, 5 of the 16 studied glacial lakes are identified as highly hazardous. In the downstream area, there are two villages with 200 inhabitants and an army camp within the zone of highest vulnerability. The identified vulnerability zones may be used by the local authorities to take caution of the threatened villages and infrastructure and for risk analysis for planned future hydropower plants.