Susceptibility of glacial lakes to avalanche and rockfall in the Hindu-Kush-Himalaya

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The Hindu-Kush-Himalayan region is home to numerous glacial lakes. Some of these lakes could fail and produce hazardous Glacial Lake Outburst Floods (GLOF). GLOFs are primarily triggered by an avalanche or a rockfall entering the lake that generates an overtopping displacement waves. In the present study, we investigate the susceptibility of all lakes present in the Hindu-Kush-Karakorum (HKH) region (Randolph Glacier inventory region 14 and 15) to the dynamic mass movement (avalanche and rockfall). Avalanche and rockfall trajectories are developed considering various depths and “Minimum Look-Up Angle” (MLUA: a term used to define the avalanche runout distance). These trajectories are also validated against the results obtained from the Rapid Mass Movement Simulation (RAMMS) model. The mass movement of avalanche or rockfall along the major axis may enhance the wave run-up leading to a higher impact on the damming structure. Therefore, each susceptible lake is critically assessed for the angle of intrusion of a mass movement. The stability of the glacial lakes was also evaluated using the steep lake front area method to understand the associated hazard. Obtained results suggest that out of 3725 glacial lakes, 239 are susceptible to an avalanche when the mean avalanche depth is considered 50 m, and only 43 if the assumed mean avalanche depth is reduced to 10 m. Furthermore, the rockfall trajectories suggest that 343 lakes are susceptible to rockfall while considering MLUA of 17°, which falls to 217 when MLUA is increased to 23°. Overall, glacial lakes in the Central Himalayas were more susceptible to mass movement than the Karakoram, Western and Eastern Himalayas. We hope that our work will enable stakeholders to make a well-informed decision for hazard management in the Hindu-Kush-Himalayas. In addition to this, developed avalanche and rockfall trajectories will also help identify critical regions and hazard susceptibility structures.