Abstract

The Northwest Himalayas serve as a critical water tower for over a billion people and harbour cryospheric reserves highly vulnerable to climate change. Intensifying climate extremes, accelerated glacier retreat, and expanding glacial lakes have increased geohazard frequency across this region, yet integrated assessments linking these processes to multi-hazard susceptibility remain limited. This thesis addresses that gap through three interconnected objectives: analysing future projections of climate extremes, assessing landslide and glacial lake outburst flood (GLOF) susceptibility, and simulating downstream flood consequences through hydrodynamic modelling. Climate extremes were characterised using 27 ETCCDI indices from ERA5-Land reanalysis (1980–2022), a 120-year district-level IMD analysis across 49 districts of the four mountain states, and projections from 13 bias-corrected CMIP6 models. Historical trends revealed contrasting signals: drying in the Upper Indus, near-stationarity in the Upper Ganga, and significant wetting in the Qura Qush basin. Despite this heterogeneity, CMIP6 projections unanimously indicated future intensification of extremes, with days exceeding the historical 99th percentile projected to increase by 32% under SSP1-2.6 to 117% under SSP5-8.5, compressing the historical 50-year event to approximately 1.5 years under the highest scenario. Temperature trends were spatially coherent, with hot days and warm nights increasing significantly across the region, driven by snow cover reduction and upper-tropospheric circulation anomalies. Landslide susceptibility in the Upper Ganga sub-basin was mapped using Random Forest, XGBoost, and Support Vector Machine models trained on over 7000 landslide records and 16 conditioning factors. Random Forest achieved the highest performance, with precipitation-related variables contributing 18% of feature importance. For GLOF susceptibility, 1358 glacial lakes above 3000 m were assessed using a 15-factor Analytic Hierarchy Process integrated with TOPSIS and COPRAS frameworks. Total glacial lake area increased by 8.71% between 2018 and 2022, with 6–8 lakes classified as high susceptibility; retrospective validation confirmed 70% correct identification of historical outburst lakes. A HEC-RAS 2D simulation of a potential outburst from Gepang Gath Lake produced a fast-rising flood pulse inundating 6.65 km^2 along a 30.4 km corridor, with 76% of the flooded area falling within the very high hazard class ($DV \geq 7.0$ m^2/s). Coupling these results with CMIP6 R99p projections, the releasable lake volume is projected to increase by 32% to 117% across SSP scenarios, directly linking climate amplification to future flood exposure. Together, these results document a coherent cascade linking climate extremes, cryospheric change, geomorphic instability, and downstream hazards in the Northwest Himalayas, providing a scientific basis for multi-hazard risk management and climate adaptation planning.