LANDSLIDE MONITORING, HAZARD AND RISK ASSESSMENT USING SPACE AND AIR-BORNE REMOTE SENSING, A CASE STUDY OF KAGHAN VALLEY, PAKISTAN

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Abstract

Landslides have devastating effects on communities, infrastructure, and the environment, making them one of the most recurring and harmful natural hazards globally. Assessing landslide hazard, vulnerability, and risk is crucial for effective mitigation and land use planning, but this is often inadequate in regions that lack data or are complex. This study proposes an integrated approach of freely available geospatial data and semi-quantitative techniques to evaluate landslide hazard, vulnerability, and risk in one of the most landslide-prone valleys i.e., Kaghan Valley, northern Pakistan along with the detailed landslide characterization and RAMMS-DF-based simulation. It also focuses on the large-scale debris flow hazard and risk assessment. The Google Earth Pro, high-resolution DEM and satellite images are used to develop a landslide inventory and assess the landslide hazard and risk assessment in Kaghan Valley. The landslide susceptibility map is then integrated with landslide-triggering factors to derive a Landslide Hazard Index map. A geospatial database of element-at-risk data of 66282 building footprints, typological data, road network, population, and land cover are obtained through remote sensing and extensive field surveys. A spatial technique is used to study this

database for vulnerability assessment, and a semi-quantitative technique is applied to assess relative risk classes for risk assessment. The landslide risk assessment map is classified into five classes from very low to very high. Using UAV surveys for the detailed characterization of the landslides which were carried out in April 2019, August 2019, and July 2022, this study evaluates the dynamics of the Nara and Nokot landslides in Balakot, northern Pakistan. Pix4D mapper was used to create orthomosaics and DSMs, which were then carefully orthorectified using GNSS and GCPs. Active depletion and transition zones were discovered using the Geomorphic Change Detection technique. While Nokot displayed a total displacement of 6,486,121.30 m3, Nara experienced a retrogressive displacement of -201.6 m with a volume loss of 4,565,274.96 m3. This study emphasizes how useful UAV technology is for detecting large-scale landslide displacement. For the assessment of debris flow hazard and risk, the advanced RAMMS-DF numerical simulation tool, a comprehensive simulation-based hazard and risk assessment was undertaken, utilizing the Voellmy model. Calibration of the model was achieved through a meticulous back analysis of a notable debris flow event on 24th October 2023 using DJI Inspire II unmanned Aerial Vehicle (UAV), facilitating the determination of crucial frictional parameters (= 0.07, = 550 m2/s). These parameters were instrumental in conducting hazard assessments for three potential release areas. The results highlight potential scenarios where debris flows could destroy the Hassa village community and Infrastructures with calculated economic losses of more than USD 20 million. This study also integrated the landslide hazard, vulnerability and

risk assessment on a larger scale with 44.73% of the area in the moderate, 34.98% of the area in high and 15.5% of the area in the very high hazard zone with more than 120 housing structures including schools and hospital are at significantly high risk to debris flow. The significance of this study lies in its ability to offer numerical insights into flow intensity factors, especially in regions with limited historical data. By combining hazard assessments with vulnerability analyses, the study provides a holistic perspective on the potential impacts on surrounding communities and infrastructure. This research emphasizes the significance of proactive risk mitigation techniques in light of the identified threats. To improve overall resilience and safety for the local population and infrastructure, the findings are intended to direct relevant agencies in the development and implementation of efficient strategies to limit the effects of debris flows in the mountainous regions of northern Pakistan. In light of the identified risks, this research underscores the importance of proactive risk mitigation strategies.

Key words: Kaghan valley, landslide, debris flow, RAMMS-DF, UAV, Simulation, Hazard, Vulnerability, Risk, Un-Manned Aerial Vehicle (UAV), GCD, Surface Movement, Point cloud, Orthomosaic, DSM