REGIONAL AND LOCAL SCALE LANDSLIDE HAZARD, VULNERABILITY AND RISK ASSESSMENT IN DISTRICT GHIZAR NORTHERN PAKISTAN.

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Session: 2019-20
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Abstracts

Geohazards mainly landslides and debris flows are the most recurrent and devastating natural disasters worldwide in mountainous terrain with significant and increasing impacts on society, economy, and the environment. Given the rough topography, high seismicity, active tectonics, monsoonal climate and human activities, the mountainous ranges in northern Pakistan have been frequently witnessed to widespread and damaging landslides, debris flow, and floods with devastating impacts on the surrounding communities, infrastructure regional and national economy. Implementing effective measures for mitigating landslides and debris flows requires comprehensive hazard, vulnerability, and risk assessment maps, especially in mountainous zones like northern Pakistan. Unfortunately, such maps are rarely available for many of these regions. These assessments are crucial because they provide valuable insights into the potential risks posed by landslides and debris flows, allowing authorities and communities to prioritize resources, plan land use effectively, and develop strategies for disaster preparedness and response. The aim of this study is to conduct a comprehensive assessment of landslide and debris flow hazard, vulnerability, and risk on both regional and local scales. These assessments utilized geospatial data and extensive field data, combined with a series of analytical approaches to analyze the risks posed by these natural hazards. The regional scale risk assessment is carried out separately for landslides and debris flows, whereas, the site-specific assessment is performed for debris flow by using high resolution images acquired through Unnamed Aerial Vehicle (UAV) and the Rapid Mass Movement Simulation (RAMMS) software is used for debris flow runout simulation. This study is carried out in the Hindukush Mountain ranges in the Ghizer district of northern Pakistan. The study area is historically active to landslides and debris flow with significant population exposed to the hazards on the alluvial fans.

Following the regional scale hazard and risk assessment, a comprehensive landslides inventory has been prepared from the high-resolution satellite images and an extensive fieldwork for carried out for validating the landslides inventory, the landslides inventory was updated accordingly. The landslide causative factors (geological, topographical and anthropogenic) are correlated with the landslide inventory using a bivariate statistical model to develop a landslide susceptibility map which is subsequently integrated with landslide-triggering factors i.e., rainfall precipitation and Peak ground acceleration (PGA) to derive a Landslide hazard Index map. A comprehensive set of indicators of the element-at-risk data including the population, building's

footprints, accompanied by typological data, roads, agriculture land, forest, and water body has been developed, from the acquired remote sensing data and extensive field surveys for the vulnerability assessment of the landslides. By integrating these indicators into the vulnerability assessment, the study aims to provide a comprehensive understanding of the potential impacts of landslides on various elements-at-risk. Subsequently, it is analyzed using a spatial multi-criteria evaluation technique to determine the landslides induced physical, environmental, and social vulnerability maps. Subsequently, all the three vulnerability maps are integrated to assess the landslide integrated vulnerability and further applied in a semi-quantitative approach for the landslide risk assessment. Similarly, through combining GIS and remote sensing (RS) technology and field data, we carried out a systematic risk analysis for debris flow. Morphometric analysis has been performed at catchments level to demarcate the debris flow prone catchments in the study area. To evaluate the impact of topography on debris flows, a set of morphometric and other parameters is prepared with additional field information. Accordingly, ascertaining the formation conditions and distribution patterns of debris flows, the hazard is calculated by applying the hazard analysis method. Moreover, the debris flow vulnerability is assessed for the alluvial fans with the associated basin where the local communities are mostly exposed to debris flows. For the regional risk of debris flow, the distribution of the risk degree is analyzed based on the results of the hazard and vulnerability analyses. This information can inform decision-making processes and help prioritize mitigation and preparedness efforts to reduce the risk posed by landslides in the study area.

For local scale assessment, a 3D numerical simulation tool, RAMMS (rapid mass movement simulation) was used to estimate the intensity parameters such as runout distance, flow velocity, height, and pressure along the path of the flow based on the Voellmy model. The high-resolution DEM acquired through UAV flights and Pix4D mapper was mosaicked with ALOS PALSAR DEM as an input for the RAMMS. Three potential release areas were considered with different initial volumes and the results were combined to assess the flow of material and other intensity parameters for various scenarios that could occur in the future. The outputs of the RAMMS were exported to ArcGIS to degenerate the debris flow hazard vulnerability and risk maps at local scale. The impact of the debris flow hazard on the surrounding communities is carried out through the vulnerability assessment and finally combined with the hazard assessment to assess the risk.

This is one of the first detailed studies assessing the risk posed by landslides and debris flows in the data poor region which may be replicated by future researchers in the areas with similar conditions. Moreover, the regional and local scale assessment results show that the distribution of high and very high risky zones where the economic activities are quite high and closely associated with the characteristics of the population and the catchments topography. The derived results shall assist the decision makers for developing and implementing landslide/debris flow mitigation and risk reducing strategies.