

Cartographic Aspects of Landslide and Mudflow Hazard Assessment in Kakheti Region (Georgia)

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Abstract:

Georgia's mountainous terrain exposes it to a range of natural disasters, with seismic activity triggering landslides and mudflows. These phenomena pose significant threats to the population, infrastructure, and economy. The expanding risk area is evident from data collected by the Department of Geology. Historical reports from the Kakheti region highlight the persistent challenges posed by mudflows and landslides, underscoring the need for effective mitigation strategies.

The Kakheti region, situated in eastern Georgia, spans 11,375 square kilometers, comprising 16.3% of the country's total territory. As of January 1, 2023, it housed a population of 306,216 people, with an average density of 26.9 individuals per square kilometer across its eight municipalities: Telavi, Akhmeta, Kvareli, Lagodekhi, Gurjaani, Sagarejo, Signaghi, and Dedoplistskaro.

Regarding the study of landslides and mudslides, it should be noted that it has almost 150 years of history in Georgia, and during this time, not so little material has been accumulated. Kakheti region is distinguished by the development of landslides and mudslides, where the deterministic basis is the precondition for the process to occur. And the stochastic factors contribute to the violation of the homeostasis established in the geological system, the stimulation and reactivation of processes.

Geomorphologically, Kakheti's rugged terrain is a transition zone between Georgia's mountainous regions, encompassing orographic units like the main Caucasus watershed range, the Tusheti, Kakheti and Gombori ranges, as well as the Iori highlands and Alazani Valley. This landscape comprises diverse elements, from highland terrains with steep slopes and gravity- flood processes to medium and low mountainous regions with deep valleys and alluvial cones, and plateaus characterized by synclines and anticlines.

The geological composition of Kakheti is diverse, spanning various ages and thicknesses of rocks, from Lower Jurassic to modern Quaternary layers, with sporadic occurrences of Paleozoic-metamorphic rocks. Notably, Jurassic homogeneous flysch-terrigeneous sediments dominate, particularly within the Kakheti Caucasus, featuring thick layers of clay shales and sandstones intermixed with quartz veins. The region is divided into three significant geotectonic units: the eastern subduction zone of the main Caucasus range, the Kazbegi-Lagodekhi zone, and the eastern subduction zone of the Georgian belt, each contributing to the area's geological complexity.

Kakhetian diverse climate conditions range from subtropical continental to temperate, with the lowlands being among Georgia's warmest regions. Precipitation levels vary too, increasing from 300 mm to 600-800 mm in the Eldari Valley.

Hydrographically, Kakheti boasts abundant internal water sources, with the Alazani and Iori rivers being primary hydrographic arteries, both belonging to the Mtkvari basin. These rivers originate in the high Caucasus mountain zone, contributing to the region's rich hydrological network.

The Kakheti region presents three distinct territorial areas, each with its geological structure and natural hazard characteristics. These areas include the middle and high mountain morphostructure, the middle and low-mountain Tsiv-Gombori range, and the Iori Plateau. Notable examples include the Duruji River valley for the first area, Telaviskhevi for the second, and Laphiani Khevi for the third.

Landslides are predominantly found in the high and medium mountain zones, particularly on the southern slopes of the Caucasus and the Tsiv-Gombori range. They are often sources for mudflows, especially triggered by neotectonic movements. Mudflows, numbering over 200 channels in Kakheti, pose threats to urbanized areas and infrastructure. They vary depending on geological formations, with the Caucasus valleys featuring denser, more destructive mudflows compared to lower density events of the Tsiv-Gombori range.

The study utilized data from the Department of Geology and the National Environment Agency to assess landslide and mudflow hazards in the region, as well as data from the National Statistical Service of Georgia to analyze municipality population and

settlement distributions. The results show variations in hazard risks across municipalities, with some facing higher risks due to their geology and morphology.

The hazard ratio analysis classified municipalities into high, medium, and low-risk categories based on the number of settlements under hazard compared to the total number of settlements. This analysis provides valuable insights for risk assessment and disaster management planning in the Kakheti region.

After processing the aforementioned data, maps depicting the general characteristics of settlements (including their area, population, and number of settlements) were prepared as part of the research. Additionally, they provided information on mudflow and landslide numbers in the target municipalities, as well as the hazard ratio and other relevant factors.

In the Kakheti region of Georgia, historical records indicate a significant history of mudflow and landslide occurrences, which have often led to adverse consequences for local settlements, including human casualties. Recent analysis has delved into the current hazard levels across various municipalities in the region. It reveals that Sagarejo and Gurjaani municipalities are situated in high-risk zones for landslides, indicating heightened susceptibility to such geological events. Conversely, Dedoplistskaro, Lagodekhi, and Kvareli municipalities face lower risks of landslides.

Geological structure and relief belong to those permanent factors which are practically unchanged. Tectonic movements and climatic conditions belong to slowly changing factors, while meteorological events, hydrological regime, seismic movements and agricultural activities belong to rapidly changing factors.

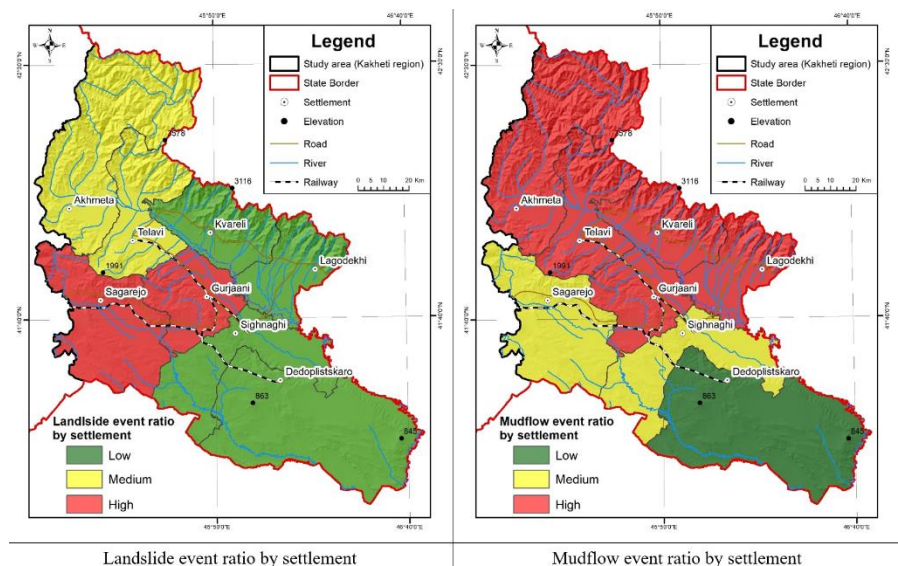
The methodological basis for the identification of landslide and mudslide centers in Georgia is based on such an approach. Within the framework of this study, we used the data of the Geological Department of the National Environment Agency and the National Statistics Service, based on which we determined the hazard coefficient for each municipality in the following manner.

The development and activation of natural geological processes is completely due to the complexity of the geological structure and tectonic conditions of the territory, the contrast of the terrain and climatic conditions, and the high human anthropogenic pressure on the geological environment.

As a result of the research, the number of settlements, population and total areas of the municipalities were analyzed. Next step was to determine municipalities and settlements, within which landslide and mudflow events are recorded and population and infrastructure object from these settlements are under hazard risk.

The analysis was carried out based on municipalities, where a hazard ratio for each was determined. The ratio of the number of settlements at risk of hazards to the total number of settlements in the municipality (Settlements under hazards/total number of settlement). The ratio was classified into 3 classes – high (>0.5), medium (0.3-0.5) and low (0.0-0.3).

Municipality	Landslide	Mudflow
Akhmeta	0.402	0.580
Gurjaani	0.645	0.839
Dedoplistskaro	0.188	0.250
Telavi	0.333	0.700
Lagodekhi	0.059	0.515
Sagarejo	0.617	0.426
Sighnaghi	0.238	0.476
Kvareli	0.045	0.545



Turning to the threat of mudflows, settlements within Akhmeta, Telavi, Kvareli, Gurjaani, and Lagodekhi municipalities are identified as high-risk areas. These regions are particularly vulnerable to the destructive forces of mudflows, posing significant challenges to local infrastructure and communities. In contrast, Dedoplistskaro municipality registers a lower risk level concerning mudflow incidents. This analysis underscores the persistent and varied threats posed by natural hazards in the Kakheti region, highlighting the importance of ongoing monitoring and mitigation efforts to safeguard local populations and assets.