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NAVIGATING DIVERGENT PERSPECTIVES: ASSESSING LANDSLIDE RISK PERCEPTION IN WESTERN NORWAY

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The subjective perception of landslide risk among the local population can deviate from scientifically assessed risk maps, as it is often shaped by personal experience, cultural beliefs, and immediate concerns. In this study, we explore the perception of landslide risk among different groups, consisting of inhabitants from three landslide-prone villages located in Aurland municipality in western Norway. The goal is to provide a basis for developing risk management strategies aligned with local priorities. Based on preliminary scoping activities in the area and the outcomes of two engagement workshops in one of the villages,a survey was sent out to the inhabitants in allthree villages to systematically collect relevant risk perception data. The main outcome of this study is that most of the respondents are quite concerned about landslides; however, reducing the current landslide risk is not highly prioritized.

Keywords: Perception of risk; Landslide; Local knowledge; Participatory process; Survey analysis

1. Introduction

In landslide-prone areas, the local population's perception of risk, shaped by personal experiences, cultural beliefs and historical events, often diverges from scientifically derived risk assessment. Understanding this discrepancy is crucial for developing risk management strategies that align with local priorities. In this study, we explore the perception of landslide risk among different groups, consisting of inhabitants in three landslide-prone villages; Flåmsdalen, Undredal and Skjerdal, all located in Aurland municipality in Western Norway.A survey was developed to explore landslide risk perception and potential explanatory factors, as well as to assess people's trust in existing landslide hazard maps and related building regulations. This paper presents the background for designing the survey, followed by an analysis and discussion of key findings on the perception of risk. The study is performed as a part of the NATURACT project, funded by the Norwegian Research Council, which focuses on upscaling nature-based solutions (NbS) for climate mitigation and adaptation.

2. Background

2.1. *Study area*

In order to understand where and how natural hazards are affecting the local population in Aurland municipality, the interdisciplinary NATURACT team, consisting of geotechnical engineers, geologists, landscape architects, climate scientists, cultural heritage specialists and systemic designers, applied a systems-oriented design (SOD) approach (Birger, 2013) to the area. Firstly, the team assessed available information about the local population, landscape, cultural heritage and natural hazards in the municipality, working both individually and collectively in workshops and through field visits. Additionally, unstructured interviews were conducted with key persons in the community, such as employees in the municipality, the Regional Parks in Norway, the agricultural office in Aurland and the tourist operator "Norway's best". From this assessment, the three villages Flåmsdalen, Undredal and Skjerdal were selected as the most relevant sites to study natural hazards and potential risk reduction measures using NbS (Fig. 1).

The landscape Aurland municipality consists of fjords and mountains with small, populated areas concentrated in the lower river valleys. The mountainsides are steep resulting in frequent rock falls and avalanches. The three villages of interest are all located along the Aurlandsfjord (Fig. 1). The north-south oriented valley Flåmsdalen is the largest village of the three, and the panoramic trainline "Flåmsbana" runs through this area. The west and east sides of the valley differ geologically, with the bedrock on the west side consisting of gneiss, and on the east side phyllite. The valley Undredal is also north-south oriented, but it is a smaller and narrower valley than Flåmsdalen. The bedrock is composed mainly of gneiss in addition to gabbro above approx. 1000 m asl. on the west side of the valley. The smallest village, Skjerdal, is locatedon the hillside above the fjord at approx. 200 m a.s.l., and the bedrock in this area is composed of gabbro. The only road leading to the village was ranked by the Norwegian Public Roads Administration (NPRA) as one of the ten most landslide prone roads in Norway in 2023(NPRA, 2023). Flåmsdalen, Undredal and Skjerdal have populations of 436, 57 and 12, respectively, whereas the municipality has a total population of 1774 inhabitants (Statistics Norway, 2023). The main income sources for the inhabitants in the study sites are agriculture, particularly goat milk production and sheep breeding, as well as tourism.

2.2. *Landslide hazard*

The landslide and snow avalanche hazard in selected areas in Aurland with high population density was mapped by the Norwegian Geotechnical Institute (NGI) on behalf of the municipality in 2016 (NGI, 2016) and the Norwegian Water and Energy Directorate (NVE) in 2023 (NGI, 2023) (yellow-to-red-colored areas in Fig. 1a, b and c). The assessment includes the preparation of maps in accordance with the requirements of the national "Regulations on technical requirements for construction works" (DIBK, 2017), which show hazard zones for landslides and snow avalanches with a nominal annual probability of 1/100, 1/1000 and 1/5000. The probabilities apply to events that pose a risk of loss of life and damage to buildings. The mapping methodology is based on field investigations andmodellingaccounting for local conditions.

In both Flåmsdalen and Undredal, the hazard is generally increasing from the valley bottom and up along the hillsides (Fig. 1a and b). In Skjerdal, the hazard is highest in the steepest parts of the hillside (Fig. 1c). Similar for all three sites is that almost all the houses are located in low-hazardous areas.

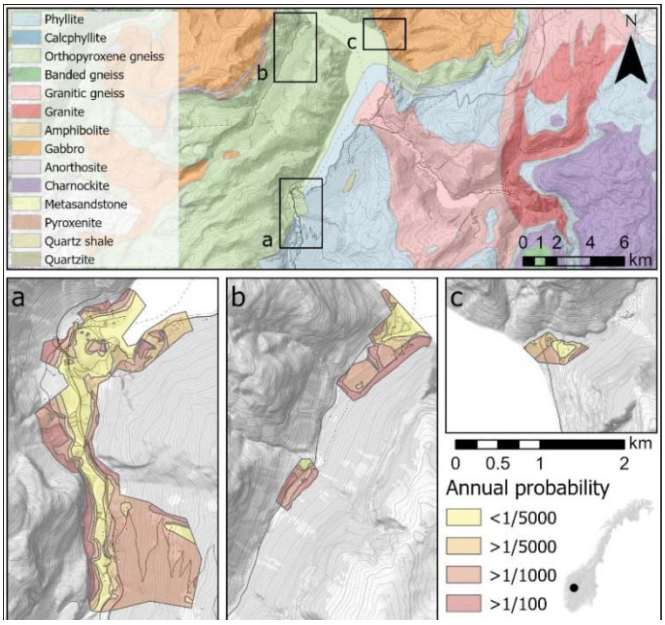

Fig. 1.The top map shows an overview of Aurland municipality and it's geology (The Geological Survey of Norway, 2022), including the location of the studied villages (a) Flåmsdalen, (b) Undredal and (c) Skjerdal. The bottom three figures show the mapped hazard for landslides and snow avalanches in the study areas. Grey areas have not undergone hazard mapping. In the lower right, a map of Norway with a black dot indicating the position of Aurland.

3. Method

3.1.*Background for developing the survey*

Further to the preliminary scoping activities to select the areas of focus within Aurland municipality, the NATURACT team contacted selected stakeholders from each of the sites to assess the inhabitant's interest in the project and willingness to participate in engagement workshops. These exchanges resulted in the village of Undredal being selected for conducting workshops where the inhabitants could share their local knowledge with the project team. Subsequently, two stakeholder engagement workshops were held in Undredal in the winter of 2023. The scope of the first workshop was for the project team to learn from the local population's experiences with natural hazards, and the scope of the second workshop was to discuss possible NbS to address the hazards the local inhabitants found most pressing.The collective feedback from both the unstructured interviews and the two engagement workshopswith the inhabitants regarding the risk of landslides was that landslides occurred frequently and often led to closed roads, but they were not concerned that these events could directly harm them. In Undredal, inhabitants were more concerned with flooding and pressure on infrastructure from tourism than with landslides. The feedback was unexpected, given the actual landslide hazard in the area, and it sparked the idea of further exploring the inhabitants' perception of landslide risk. A systematic survey was chosen as the research method, as it would provide feedback from a large group of individuals, offering a broader overview compared to other methods, such as structured interviews.

The survey structure was inspired by the work of Anderson et al. (2021). In their study, a survey focusing on exploring the underlying factors governing the public acceptance of NbS for natural hazard risk reduction was sent out to inhabitants in the landslide-prone area Catterline in Scotland. Risk perception was one of the key factors they investigated, hence the questions on this topic used in their work werereutilized in this study. Similar to Anderson et al. (2021), questions regarding place of living, age, gender, profession were included. The survey included Likert items with five options ranging from "Strongly Disagree" to "Strongly Agree", "Yes/No" questions, multiple choice questions and open-ended questions. For both the Likert and yes/no questions an option to answer "I do not know" was provided. The survey was conducted in Norwegian, and translations to English were carried out by the authors.

3.2. *Survey distribution and data processing*

A survey was sent electronically to the inhabitants of Flåmsdalen, Undredal and Skjerdal in March 2024. The survey was sent directly to the project team's connections in the area, as well as to all relevant organizations listed on the municipality's website. Information about and a link to the survey was also published on the municipality's website and on social media groups used by the inhabitants in the three study sites. Ethical clearance for the survey was granted by the Norwegian Agency for Shared Services in Education and Research, and all the data was treated anonymously. A total number of 25 responses were received, where six (1.4% of population), eight(14% of population) and three(25% of population) responses belonged to inhabitants in Flåmsdalen, Undredal and Skjerdal, respectively. The remaining eight responses were from people living in other places within the municipality that had participated in the survey even though it was not strictly directed towards them. In the analysis of the results of the survey, these responses are included when the term "all respondents" is used, and excluded when the responses from the three different study sites are treated separately.

During data processing, the verbal answers to the Likert questions were given scores from 1 to 5, where 1 and 5 correspond to "Strongly Disagree" and "Strongly Agree", respectively. The values were then normalized to a score between 0 and 1. When respondents answered "I do not know" to a Likert question, a mid-point response score was assigned. Due to the small sample size, the data could not be processed in the same manner as Anderson et al. (2021). Instead, a"risk perception score" was computed as the average value of a respondent's answers to all the survey items on this topic. Finally, these scores were classified into five equally sized classes ([0.0,0.2), [0.2, 0.4), [0.4, 0.6), [0.6, 0.8), [0.8, 1.0]), ranging from "very low" to "very high".

4. Results

Reviewing the responses to the survey of all the respondents together, the respondents are well-distributed with respect toboth gender and age. However, the sub-groups of Undredal, Flåmsdalen and Skjerdal have slightly less even distributions. For Undredal, most of the respondents are women over 45 years of age, whereas for Flåmsdalen most of the respondents aremen between 35 and 65 years. Skjerdal has only two male and one female respondents, all between 35 and 65 years. Over 30% of all the respondents are working with agriculture, whilst above 10% work in the municipality or the education sector. The remaining respondents workwith either construction, healthcare, media, sales or tourism, or are managers, self-employed or retired (1-2 responses per sector). When asked what the advantages of living in Aurland are, the three most frequent answers are "the natural scenery", "the nature" and "the possibility for recreation and hiking". On the other hand, the three most frequently named disadvantages are "landslide hazard", "flood hazard" and "prone to harsh weather".

The average responses to the individual survey items describing risk perception for all the respondents and the different sub-groups are shown in Fig.2. Each of the four groups has different items ranked as their most important contributor to risk perception. The item with the lowest score varies among the three different sub-groups, while the Skjerdal sub-group and the group containing all respondents both give the lowest score to the same item ("Landslides are a threat to the health of the land and its species"). Cumulatively (i.e., considering the sum of the responses of all four groups), the question "Landslides in the area where I live will be stronger and more frequent in the future" receives the highest score, whilst the question "Landslides are a threat to the health of the land and its species" receives the lowest score.

In Fig. 3, the distribution of risk perception classes is presented as relative shares of total responses for all the respondents and the tree different sub-groups, enabling comparison while accounting for their differing sizes.For example, 25% of respondents in Undredal belongs to the "medium" class, corresponding to two persons (25% of 8). For all the groups, the class "high" risk perception is the largest. For the group containing all respondents, perceived risk ranges from "low" to "very high". For Undredal, represented classes are "medium" to "very high", whilst the risk perception is somewhat lower in Flåmsdalen, where the representedrisk classes are "low" to "high". In Skjerdal, two respondents are assigned to the "high" risk class, whilst one respondent is assigned to the "very high" risk class.

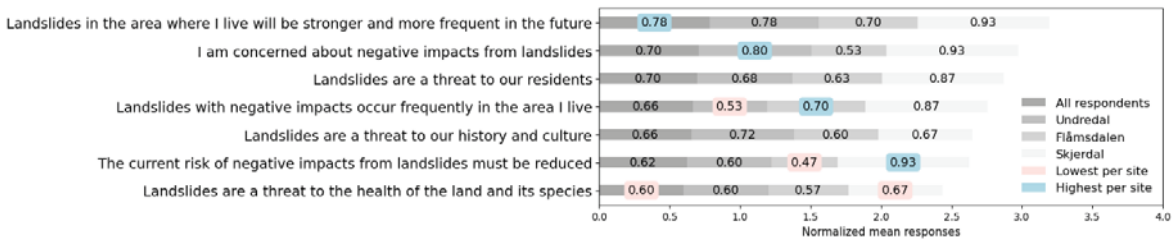

Fig. 2. Normalized average responses for survey items related to landslide risk perception for all the respondents, and separately for the three villages: Undredal, Flåmsdalen and Skjerdal. Higher scores indicatea higher perception of risk.

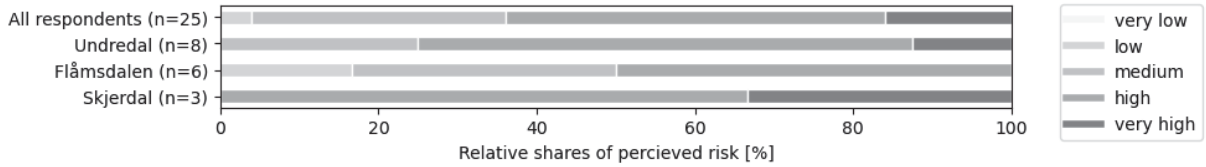

Fig. 3.Relative shares of perceived landslide risk amongst all respondents, and separately for the three villages: Undredal, Flåmsdalen and Skjerdal. Classification into the five risk classes based on the risk perception scores.

5. Discussion

As shown in Fig. 3, the perception of risk related to landslides is higher in Undredal and Skjerdal than in Flåmsdalen. A possible explanation is that there is only one road to the small communities in Undredal and Skjerdal, making the consequence of a landslide blocking the road greater for these villages than for Flåmsdalen. Additionally, the Norwegian government agency Bane NOR SF is responsible for securing the hillsides in Flåmsdalen to protect the railway, which could contribute to a lower perception of risk among residents.

By examining the relative contribution of the individual questions to the calculation of the risk perceptionscores (Fig.2), it is evident that respondents are concerned about an increase in the frequency and magnitude of landslides in the future. Although a question about the increased impacts of climate change was not included in the survey, it is likely that this might have been implicitly assumed when responding to the question.This awareness was also evident during the engagement workshops in Undredal, where several participants reported that landslides and snow avalanches are occurring more frequently, and at different times of the year than before.

In general, the participants in the survey responded that they are quite concerned about landslides and especially that they fear for the safety of their inhabitants. However, only the respondents residing in Skjerdal strongly believe that the current landslide risk is too high, and that actions must be taken to reduce the risk.

As mentioned, the inhabitants in Undredal believe that other issues, such as flooding and tourism, pose a greater threat to their society than landslides. This may in part explain why the respondents in Aurland (except Skjerdal) do not wish to prioritize risk reduction measures for landslides. Nevertheless, when asked in this survey what the main disadvantages of living in Aurland are, the landslide hazard was the most frequent answer. A possible explanation for this could be that the participants are influenced by the survey's theme, which may introduce a bias in their responses.

A limitation of this study is the relatively low number of survey respondents, both in terms of total participants and participants per village. Therefore, differences in results between the villages should be interpreted with caution. That said, the responses, representing1.4-15% of the population of the three villages, provide valuable insights that should be considered when addressing landslide risk management.

6. Conclusion

In this study, the perception of landslide risk of inhabitants in Aurland municipality, located in western Norway, is explored. Based on the results from the respondents of the survey, the risk perception varies between the three villages included and is especially high in Skjerdal and Undredal. This information is crucial for public authorities and professionals managing landslide risk, as risk perception is site specific. Particularly, low local perceptions of risk should be acknowledged during mapping activities to ensure that trust remains between authorities and local communities.Furthermore, except for Skjerdal, the results indicate that reducing the current landslide risk is not highly prioritized among the inhabitants. This information highlights a potential barrier for prioritizing landslide risk reduction interventions by the municipality. As such, public authorities responsible for protecting their inhabitants must engage with the community to understand their concerns and build trust, ensuring that risk reduction measures are both effective and supported by the local population.

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