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Review

Risk perception of climate change and natural hazards in global mountain regions: A critical review

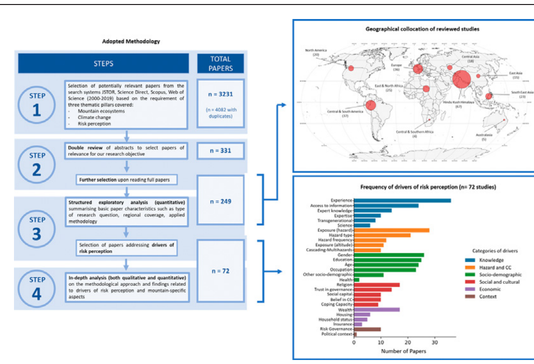
Stefan Schneiderbauer [a,b,c,*], Paola Fontanella Pisa [a], Jess L. Delves [a], Lydia Pedoth [a,c], Samuel Rufat [d,h], Marlene Erschbamer [e], Thomas Thaler [f], Fabio Carnelli [c], Sergio Granados-Chahin [g]

[a] United Nations University, Institute for Environment and Human Security, Bonn, Germany at Eurac Research, Centre for Global Mountain Safeguard Research (GLOMOS), 1 Viale Druso, Bolzano 39100, Italy
[b] Department of Geography, Qwaqwa Campus, University of the Free State, Bloemfontein 9301, South Africa
[c] Institute for Earth Observation, Eurac Research, 1 Viale Druso, Bolzano 39100, Italy
[d] Department of Geography, CY Cergy Paris University, 33 Boulevard du Port, 95000 Cergy, France
[e] Institute for Indology and Tibetan Studies, Ludwig-Maximilians-Universität, Ludwigstraße 31, 80539 Munich, Germany
[f] Institute of Mountain Risk Engineering, University of Natural Resources and Life Sciences, Gregor-Mendel-Straße 33, 1180 Vienna, Austria
[g] Faculty of Psychology, Universidad de Sevilla, Calle Camilo José Cela, s/n, 41018 Sevilla, Spain
[h] Institut Universitaire de France, 1 rue Descartes, 75231 Paris, France

HIGHLIGHTS

- Results show the lack of an integrated view of climate change and mountain hazards.
- Risk perception studies neglect urban areas in mountain regions.
- Risk perception is defined by socio-economic factors, cultural setting and governance.
- Conceptions of climate risk perception vary within and between scientific disciplines.
- A multidisciplinary digital library incl. social sciences and humanities is needed.

GRAPHICAL ABSTRACT



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ABSTRACT

Mountains are highly sensitive to climate change. Their elevated areas provide essential ecosystem services both for the surrounding mountainous regions and particularly for adjacent lowlands. Impacts of a warmer climate affect these services and have negative consequences on the supply of water, on biodiversity and on protection from natural hazards. Mountain social-ecological systems are affected by these changes, which also influence communities' risk perception and responses to changing climate conditions. Therefore, to understand individual and societal responses to climate change in mountain areas, aspects and drivers of risk perception need to be scrutinised. This article presents the findings of a literature review of recent English language publications on risk perception in connection to climate change and related natural hazards in mountain regions worldwide. Studies were selected from recorded entries in JSTOR, Science Direct, Scopus and Web of Science covering the period 2000–2019 and analysed in two steps (structured exploratory analysis, $n = 249$ and in-depth analysis, $n = 72$) with respect to the studies' research question, methodology, geographical scope and risk perception drivers.

* Corresponding author at: United Nations University, Institute for Environment and Human Security, Bonn, Germany at Eurac Research, Centre for Global Mountain Safeguard Research (GLOMOS), 1 Viale Druso, Bolzano 39100, Italy.

E-mail addresses: schneiderbauer@ehs.unu.edu (S. Schneiderbauer), fontanella.pisa@ehs.unu.edu (P. Fontanella Pisa), delves@ehs.unu.edu (J.L. Delves), lydia.pedoth@eurac.edu (L. Pedoth), samuel.rufat@u-cergy.fr (S. Rufat), marlene@erschbamer.net (M. Erschbamer), thomas.thaler@boku.ac.at (T. Thaler), fabio.carnelli@eurac.edu (F. Carnelli), sgranados@master.upeace.org (S. Granados-Chahin).

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Mountain risks
Mountain hazard processes
Climate risk reduction
Risk perception drivers

The review reveals that socio-demographic factors, like gender, age and personal experiences, have a crucial impact on individual risk perception. Some of the less tangible but nevertheless decisive factors are important in mountain regions such as place attachment and socio-cultural practices. In conclusion, there is however little information in the literature which addresses the specific situation of risk perception in mountain areas and its influence on communities' responses to environmental changes. Further, we observed a strong gap concerning the integration of indigenous knowledge in risk perception research. Many studies overlook or oversimplify local knowledge and the cultural dimensions of risk perception. Based on these results, the paper identifies several gaps in research and knowledge which may influence the design of climate risk management strategies as well as on their successful implementation.

Contents

1. Introduction

The effects of climate change on mountain regions are a cause for concern not only for the highlands themselves but in particular for the lowlands that critically depend on them in various ways. There is increasing evidence that the rate of warming augments with elevation leading to accelerating changes in mountain ecosystems and their hydrological regimes (Pepin et al., 2015; Vuille et al., 2015; Wang et al., 2016; Williamson et al., 2020). This high-altitude warming leads to impacts which have direct and indirect consequences on ecosystem services and economic activities far beyond mountainous areas. One example, and the most important aspect in terms of impacts on health, economy, livelihoods and well-being is the modification of hydrological regimes due to changes in temperature (increasing glacial melt and evapotranspiration) and precipitation (particularly snowfall). This has the potential for dramatic consequences for hydropower generation, irrigation systems and freshwater supply (Armstrong and Lazarus, 2019; Beniston and Stoffel, 2014; Beniston et al., 2018; Khromova et al., 2019; Nüsser et al., 2019). Other impacts can affect the frequency and magnitude of natural hazard processes (Gariano and Guzzetti, 2016; Gobiet et al., 2014; Schlögel et al., 2020; Stoffel and Huggel, 2012), the loss of biodiversity (Liedtke et al., 2020; Rogora et al., 2018; Steinbauer et al., 2018) and – less tangible but no less significant – the loss of cultural identity and place attachments due to modifications of mountainous landscapes (Shaw and Nibanupudi, 2015).

Adverse changes in mountain social-ecological systems call for adaptation measures in order to mitigate impacts and reduce potential loss and damage. Despite increasing knowledge regarding their underlying processes and their possible consequences, the extent of activities aiming to prepare for these challenges is often limited. While locally embedded adaptation measures are developed by communities based on local knowledge, the Eurocentric perspective of Western science does not easily account for the multiple ontologies associated with this local knowledge (Amin, 2010; Gergan, 2017; Said, 1978; Yeh, 2016).

Key factors influencing much needed adaptive behaviour are risk awareness and risk perception; 'risk awareness' describing the level of *recognition* of the potential for hazards related to climate change compared to 'risk perception', which refers to the *subjective assessment* of related risks (Lechowska, 2018). High risk awareness and perception have been identified as contributing to public support for management policies as well as for taking precautionary disaster reduction decisions (Bamberg et al., 2017; Bradford et al., 2012; Buchecker et al., 2016; Rufat et al., 2020; van Valkengoed and Steg, 2019). In recent years several empirical studies have scrutinised such drivers and characteristics of risk awareness and risk perception (predominantly looking at flood risks) (Birkholz et al., 2014; Boholm, 1998; Bradford et al., 2012; Bubeck et al., 2012; Lechowska, 2018; Raška, 2015; Wachinger et al., 2013). However, respective results are inconsistent (Bamberg et al., 2017; Bubeck et al., 2012; Kellens et al., 2013; Lechowska, 2018; van Valkengoed and Steg, 2019) or even conflicting (Attems et al., 2020; Bamberg et al., 2017; Lechowska, 2018) due to a strong influence of context-specific parameters.

This paper presents the findings of a critical literature review of English language peer reviewed publications dealing with risk perception related to climate change and its impacts in mountain regions worldwide. The review was performed by an interdisciplinary team of natural, social and humanistic scientists and seeks to provide an in-depth and comprehensive understanding of which factors influencing risk perception in mountain regions are addressed in the current literature. In recent years a number of empirical studies has scrutinised drivers and characteristics of risk perception in a variety of case studies, predominantly addressing flood risks (Bubeck et al., 2012; Wachinger et al., 2013; Lechowska, 2018). So far, no previous review on risk perception to climate change or climate-related risks in mountain regions has yet been conducted. And yet, environmental changes in mountains greatly impact the economic, cultural and religious conditions of mountain communities whether directly or indirectly. Furthermore, the focus on mountain regions is shown to be crucial to wider society as environmental changes in mountain regions highly influence lowland areas. The aim of this paper is to shed light on existing studies on risk perception in the context of climate change in mountain regions across the globe. The work has been carried out with the objective of identifying mountain specificities (if existent) and eventual related gaps in knowledge, in order to guide future research on these vulnerable and yet extremely important social-ecological systems. The focus of the review is particularly towards investigating drivers of climate change related risk perception in mountains as well as the question of whether those drivers are different from the ones influencing risk perception in lowland areas. With the presented results of this review, we intend to contribute to a better understanding of the complex issue of climate change related risks as one crucial factor for adaptation planning.

This paper begins with a description of our literature selection methodology. This is followed by the results from a first round of literature review (*structured exploratory analysis*, $n = 249$) and the results of a subsequent second round of review (*in-depth analysis*, $n = 72$) of a selection of papers from the first review. Next, a discussion section aims to identify broad trends and gaps in the literature and reflects on their implications for Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) research and risk-related policy making.

2. Methodology

This work is the result of a review of 249 English language peer reviewed studies, which deal with risk perception within the context of climate change and natural hazards in mountain regions worldwide. The methodological approach was designed as an interdisciplinary review. We therefore refrained from applying any previously developed definitions of key terms such as 'risk perception' or 'mountains' in order to embrace the variety of interpretations existing in the various schools of thought. Studies were selected from recorded entries in JSTOR, Science Direct, Scopus and Web of Science covering a 20-year period (2000 to 2019). The review was carried out between February and October 2020. It included four main working steps, the first two dealing with the selection and filter of studies (step 1 and step 2, see more detail in Fig. 1, Table 1 and in the text below). The following two working steps (step 3 and step 4) comprised various analyses. In step 3 we quantitatively analysed 249 studies, focusing on general characteristics such as type of research question, methodology and geographical scope. Step 3 is referred to as the 'structured exploratory analysis' (see Fig. 1). These 249 studies were further reduced to 72 publications that explicitly investigated one or more drivers of risk perception. During step 4

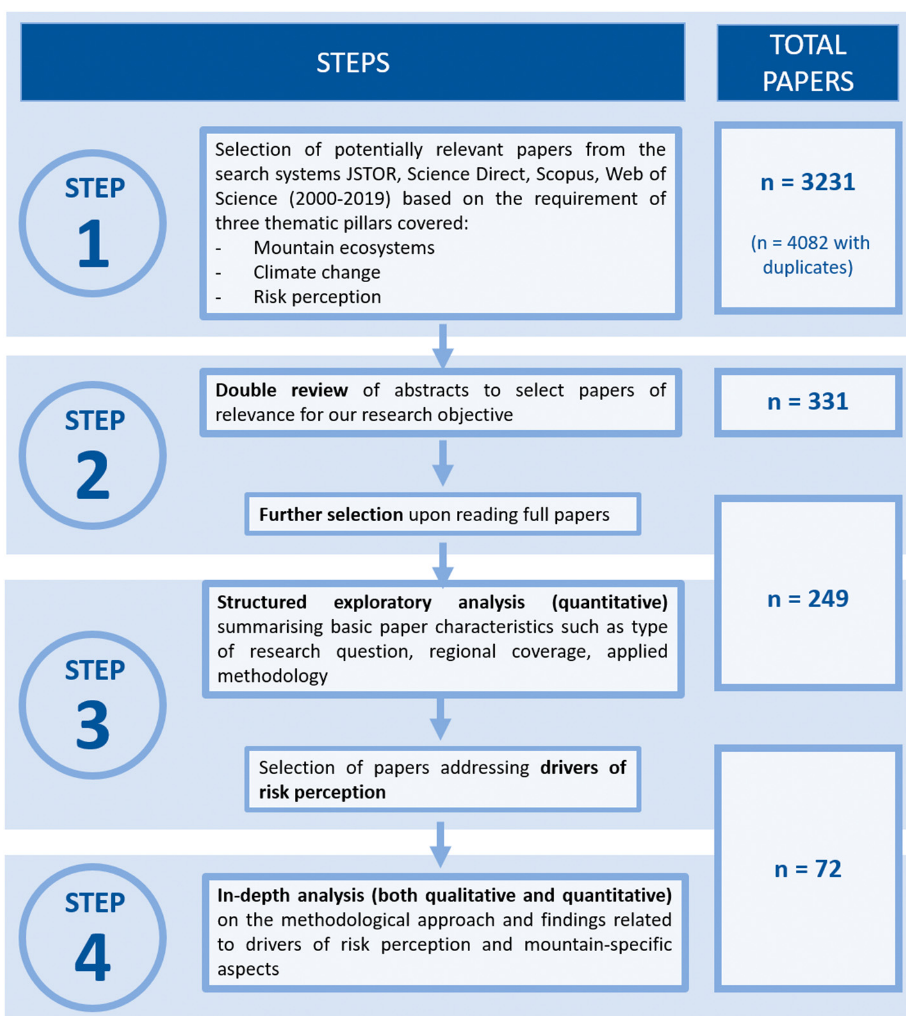

Fig. 1. Applied workflow of the four major steps dealing with the selection, filter and analysis of reviewed studies.

Table 1
Inclusion/exclusion criteria for filter process (step 2).

Classes of criteria	Inclusion	Exclusion
Mountain	Based on research in mountainous regions, or on highland-lowland relations	No link to mountains
Risk	Perception of climate change influenced risks and related hazardous phenomena	Risks that are not influenced by climate change (i.e. linked to medical issues, nuclear, chemicals etc.)
Perception	Human risk perception	Animal risk perception

these 72 publications, which represent the core mass of literature for this study, were scrutinised to identify the specificities of risk perception drivers addressed. Step 4 is referred to as the 'in-depth analysis' (see Fig. 1).

The search query contains three conceptual pillars: (i) mountain ecosystems; (ii) climate change and; (iii) risk comprised synonyms which we found to be commonly used in abstracts of the relevant literature. Three clusters served as basis for a general Boolean search query, shown below.

> (mountain* OR highland* OR "high* ecosystem*" OR alp* OR landslide* OR "glacial lake outburst flood" OR GLOF OR avalanch*) AND ("climate change" OR "changing climate" OR "global warming" OR "adverse climate" OR disaster OR hazard OR risk) AND (perception* OR "social construct" OR viewpoint OR "risk awareness" or "perceived risk")

The search was run on JSTOR, Science Direct, Scopus and Web of Science. The choice of search system is based on Gusenbauer and Haddaway's (2020) evaluation of search systems for systematic reviews in which they assess the utility of 28 search systems according to 27 criteria, including (but not limited to) database subject, size and language as well as search functionalities (e.g. search string length, Boolean functionalities, post-query refinement, advanced searching, citation/abstract/keyword/full-text search abilities). We first narrowed the selection to 11 multidisciplinary search systems and then, using the assessment table in Gusenbauer and Haddaway (2020), selected those of which the search functionalities responded to the requirements of our review. Finally, smaller search systems whose databases also appear in the major search systems were excluded to avoid duplicate entries.

The application of the query of the four selected search systems produced a total of 4082 results. Among these, 851 results were duplicates, leaving 3231 studies to review.

This list of identified 3231 studies was subject to a first filter process (step 2, see Fig. 1), based on a double review of title and abstract carried out by the authors. This filter process excluded any studies that did not include all three core criteria, namely *mountain*, *risk* and *perception* (Table 1). This selection process resulted in 331 pertinent studies. A further 82 studies were excluded prior to completion of step 3 (exploratory analysis) because - contrary to what was understood from the title and abstract - upon reading the entire text it became clear that the content of these studies did not fit the three criteria of our review. These studies were therefore disregarded in the further work.

Our analysis was conducted in two steps: structured exploratory (step 3, $n = 249$) and in-depth (step 4, $n = 72$). The exploratory analysis analysed studies that address perception of climate change influenced risks in mountain areas. From these studies, 72 studies addressing drivers of risk perception were further analysed according to new criteria.

The exploratory analysis was carried out quantitatively (step 3, n = 249) using information extracted from the whole study text which was entered into a spreadsheet. Information was collated under the following clusters: research objective; approach to risk perception (four variables); hazard type (eight variables); climate change related hazards (four variables); geographical focus (22 variables); methodology (44 variables) and sector(s) investigated (10 variables). In addition, during this first exploratory analysis studies were identified that specifically addressed drivers of risk perception. These studies were then reanalysed in the in-depth analysis (n = 72).

The second, in-depth analysis was done both quantitatively and qualitatively, based on a second spreadsheet developed for the in-depth analysis of risk perception drivers (step 4, n = 72). Information regarding risk perception drivers was collated in the following clusters: hazards and climate change (six variables); knowledge (seven variables); socio-demographic (six variables); social and cultural (six variables); economic (five variables) and context (two variables). In addition, methodology was analysed using 13 variables, focusing on the role of risk perception and risk perception drivers in the paper.

3. Results

3.1. Structured exploratory analysis

3.1.1. Review sample

Most studies relevant to the research question and selected for our review (exploratory analysis, $n = 249$) have been published after 2010 with a maximum value in 2017. The blue line in Fig. 2 shows the development of the absolute numbers of these studies per year for the years 2000–2019.

In comparison to this graph, the orange line represents the total number of published studies recorded in our four searched databases for the same 20-year period. Fig. 2 shows that there has been a disproportionate increase in studies dealing with climate-related risk perception in mountains during the last ten years when compared with total scientific publications. The first significant rise in absolute numbers of studies is visible in 2006 shortly after the South East Asian Tsunami in 2004 and the World Disaster Risk Conference in Kobe, Japan, in 2005. The peak in 2017 may have been influenced by the development of UN frameworks around 2015 such as the UNFCCC's Paris agreement, the UN Post-2015 development agenda and the Sendai Framework for Disaster Risk Reduction. Not only has there been a relative increase in research into climate-related risk perception in mountains in the last decade, but within our sample we also found there to be a relative increase in studies which explicitly address climate change (Fig. 4). This increase began in 2010, with a notable jump in 2017, which we hypothesise could also be linked to the abovementioned international climate frameworks.

The geographical distribution of the studies (step 3; n = 249, multiple entries possible) shows a strong cluster in the Hindu Kush Himalaya area, with very few in southern Africa and Australasia (Appendix 1). There were no studies dealing with the Caucasus. The most frequently represented countries are Nepal (41 studies), India (35 studies), China (20 studies), Ethiopia (18 studies), Italy (17 studies) and Peru (15 studies). Only nine studies' were conducted in mountain cities, spread between Central and South America (Barrucand et al., 2017; Shrestha et al., 2019; Wu et al., 2015; Ye et al., 2018), Italy (Calvello et al., 2016; Murtinho et al., 2013; Rasmussen, 2019) and USA (Champ et al., 2013; Cholakova and Dogramadjieva, 2019).

3.1.2. Approaches to risk perception (structured exploratory analysis)

For our exploratory analysis we distinguished four thematic clusters in the context of which our selected studies address risk perception, namely: (i) a description of risk perception, (ii) risk perception in the context of risk communication, (iii) risk perception as a factor influencing action (for example adaptation to climate change) and (iv) drivers of risk perception. Most studies (156 of 249) address risk perception with the purpose of describing it, 89 of which do so in combination with at least one other cluster.

A total of 100 out of 249 studies address risk perception as a factor influencing adaptation or mitigation actions. Of these, 29 studies only

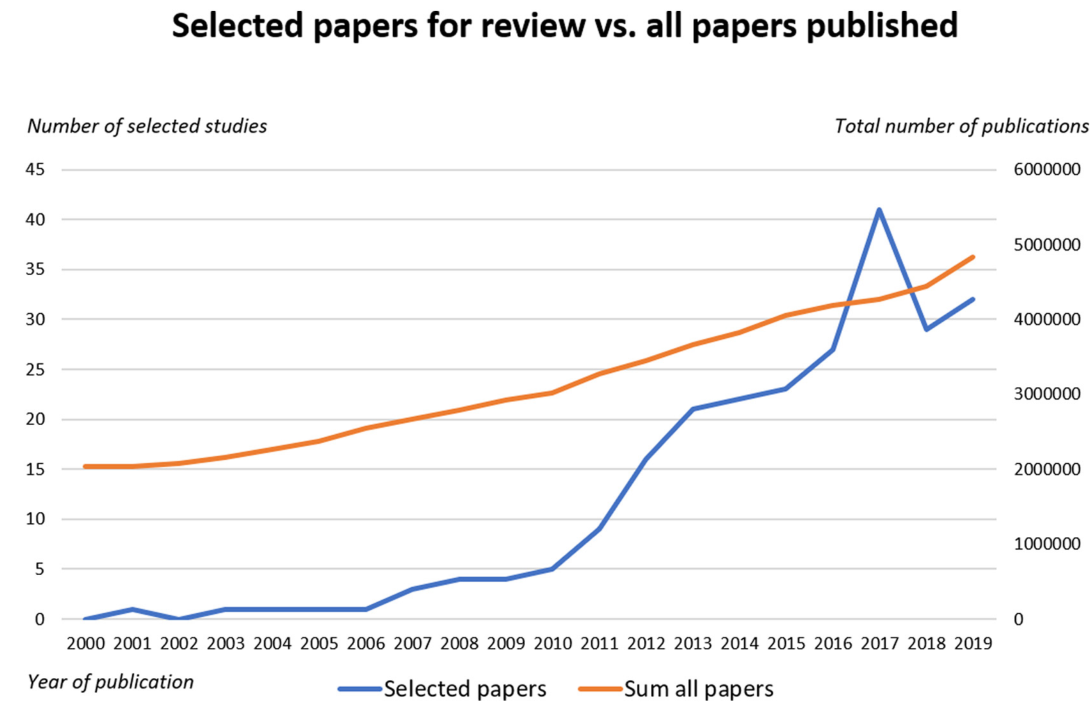

Fig. 2. Number of selected studies (step 3, n = 249) per year compared to the total number of publications recorded within the searched databases for the period 2000–2019. The blue line representing our selected and reviewed studies in absolute numbers referring to the left y-axis, the orange line representing all published studies referring to the right y-axis.

focus on this aspect of risk perception, whereas 58 studies both describe risk perception *and* address it as a factor influencing actions. The least researched aspect of risk perception in the studies reviewed was risk communication with only 27 studies.

It is important to differentiate between studies using the term 'perception' as in *observations* of changes, (where 'risk perception' equates to climate risk *awareness*), and those focusing on what factors are *shaping* risk perception (as in *subjective appraisal* of risk) of people in mountains. Sixty-seven out of 249 studies address risk perception only by describing it. Of these 67 studies, 13 studies (20%) compare climatic data and people's observations of climate change, with the purpose of validating instrumental climatic data (or vice versa). Other studies within this 67 tend to either describe impacts of climate change through the observations of communities, or to describe people's perceptions of the impacts of climate change and how they adapted to these changes.

Among the 249 studies, only 72 studies (22%) investigate risk perception drivers, while 60 (18%) question what aspects are shaping the risk perception of people in mountains, and even fewer (39, 11%) focus on defining risk perception. This is representative of the heterogeneity of uses of the term 'risk perception': while within the DRR studies this definition is relatively standardised, other disciplines use it alternatively to mean observation of risk or subjective appraisal of risk. Such heterogeneity in approaches to risk perception is further reflected by the fact that it is not common to find two comparable definitions of the concept. The mere lack of definition, absence from the research question and/or lack of detailed analysis indicate that these 'perceptions' may be invoked as proxies rather than analysed to understand what is shaping subjective appraisals of risk of people in mountains, with a few notable exceptions tackling the colonial hierarchy of knowledge (e.g. Paerregaard, 2013).

3.1.3. Fast- and slow-onset events and processes (structured exploratory analysis)

With respect to the type of risks which the studies address, we identified two clusters: the first covering fast-onset hazardous events and the second slow-onset hazardous processes and changing climate conditions. For the purposes of our review, we considered fast-onset hazardous events to be floods, storms, fires, landslides, cold waves/heat waves, avalanches and GLOFs. Slow-onset hazardous processes and changing climate conditions are precipitation changes, snow melt, glacial melt, temperature changes and water scarcity/drought. The most frequently investigated hazards in the studies are water-related (precipitation changes, floods, water scarcity) followed by temperature changes and landslides (Fig. 3). Of the studies that investigate single hazards, a majority deal with water scarcity (40 studies). However, 96 of 249 studies deal with two or more hazards. The most common two-hazard combinations are landslides and floods (40 studies) and floods and water scarcity (44 studies). Seventy-eight studies have mentioned between three and six different types of hazard.

Concerning studies that address *only* slow-onset climate change processes, the most frequently addressed were precipitation changes (148 of 249) and temperature changes (138 of 249). Additionally, we distinguished between studies that explicitly relate their work to climate change (72%) from those that do so implicitly (28%).

There is a difference between those risks investigated in the studies selected for the exploratory analysis (step 3), and the refined study selection investigating risk perception drivers (in-depth analysis, step 4) (Fig. 3). The focus on water scarcity of the former is replaced by a focus on landslides and floods in the latter.

Interestingly, 138 out of 249 studies (55%) look *either* only into slow-onset hazardous processes and changing climate conditions (80 of 249, 32%) *or* fast-onset hazards (58 of 249, 23%), while 94 studies (38%) considered both (Fig. 3). This indicates that a significant number of authors of the scientific community of Climate Change Adaptation (CCA) or Disaster Risk Reduction (DRR) look through a 'classic' (or 'traditional') lens of their discipline, in which climate changes are not considered an influencing factor in fast-onset hazards. In order to verify that hypothesis, we accounted for the sectors addressed in the studies, clustering them in 'primary' sectors (agriculture, pasture and forestry) and 'safety' sectors (settlement/built-up areas, infrastructure and people's safety).

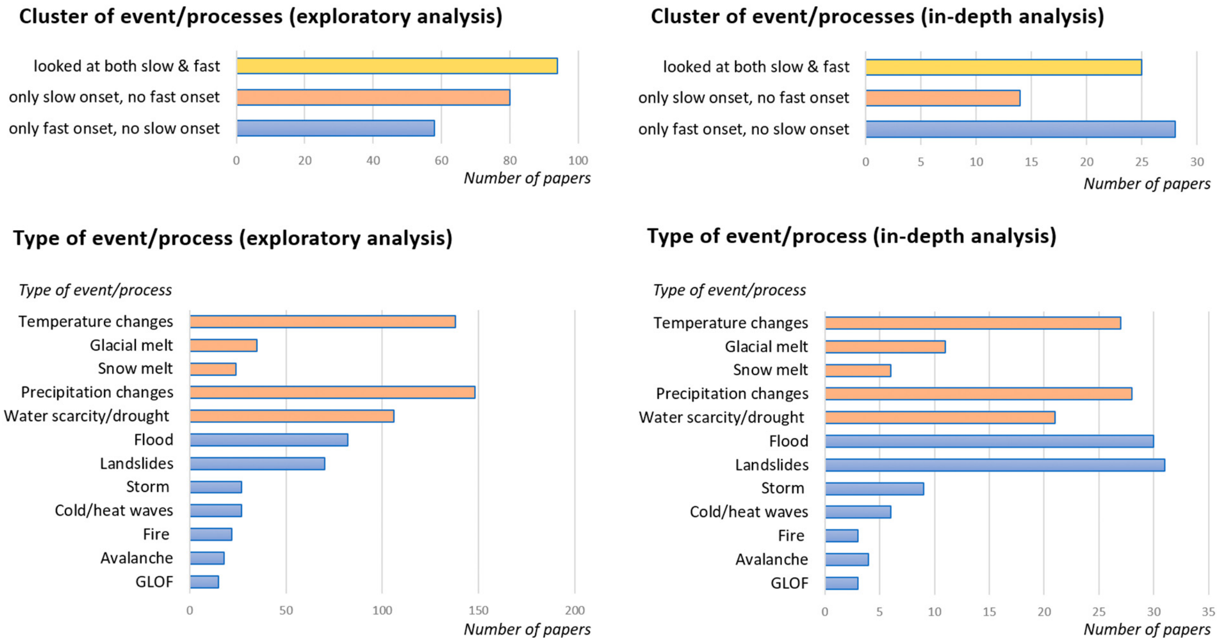

Fig. 3. Number of studies dealing with specific events/processes from exploratory and in-depth analyses. Upper left: Number of studies dealing with specific events/processes from exploratory analysis – clustered (step 3, $n = 249$); Upper right: Number of studies dealing with specific events/processes from in-depth analysis – clustered (step 4, $n = 72$). Lower left: Number of studies dealing with specific events/processes from exploratory analysis (step 3, n = 249, multiple entries possible). Lower right: Number of studies dealing with specific events/processes from in-depth analysis (step 4, n = 72, multiple entries possible).

Table 2 shows that out of the 174 studies dealing with slow-onset processes, 130 investigated one or more sectors in the 'primary' cluster (75%) but only 55 in the 'safety' sector (32%). On the contrary, of 152 studies dealing with fast-onset events, only 73 investigated the 'primary' sector (48%) but 90 studies investigated the 'safety' sector (59%). Looking at these numbers from the angle of the sectors, we find 130 studies (90%) of the 144 mentioning primary sectors linked to slow-onset processes while only 73 (51%) of them link to fast-onset events. The percentages for the 'safety' sectors show the opposite, with an overall number of 122 studies of which 55 (45%) link to slow-onset processes and 90 (74%) link to fast-onset events.

3.1.4. Methodologies of studies reviewed (structured exploratory analysis)

We identified those studies among the 249 of the exploratory analysis, which (i) represented a longitudinal study (here defined as a repetition of investigation in the same area or with the same people) and (ii) were carried out following a (hazardous) event. We found only nine studies with longitudinal studies all of which addressed climate change (six explicitly and three implicitly). Twenty-three of the 249 studies were carried out 'following an event'. Of these, 21 investigated hazards and 16 addressed climate change (with 14 linking the two). The only two studies that did not address fast-onset hazards addressed glacial retreat and drought, respectively.

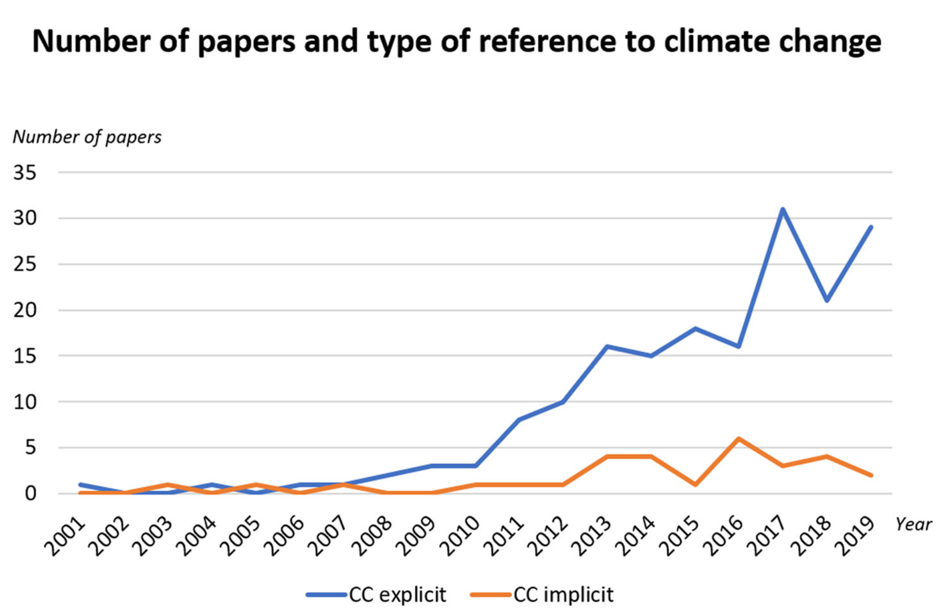

Fig. 4. Annual trend of use of climate change as variable in research (step 3, exploratory analysis, $n = 249$).

Table 2
Relation of investigated processes/events and sectors. The bold numbers indicate the overall number of studies for specific processes/events and sectors, respectively. The numbers in italic show the number of those studies that combine a specific type of process/event with a specific sector. Left of these numbers, percentage values are given relating to the number of studies of the processes/events, above these numbers percentage values are given relating to the number of studies of the sectors.

		Sectors				
		Papers (absolute number)	'primary' (agriculture, pasture, forestry)		'safety' (infrastructure, people's safety, built-up)	
Processes / events	Papers (absolute number)			**144**		**122**
				90%		*45%*
	slow onset	**174**	*75%*	*130*	*32%*	*55*
				51%		*74%*
	fast onset	**152**	*48%*	*73*	*59%*	*90*

Research methods varied in our sample of studies. In total, 94 of 249 studies use mixed methods (38%), 57 used qualitative (23%) and 94 quantitative (38%). In terms of the relationship between climate change and methodology, there was no significant difference between approaches: 73 of the 94 (78%) mixed methods studies explicitly addressed climate change, with comparable figures in qualitative (74%) and quantitative (68%) studies. Fig. 6 shows the distribution of investigated hazards – clustered in fast- and slow-onset – in relation to methodological approaches. Distribution is relatively equal with a slightly larger proportion of quantitative studies dealing with climate parameters. It is notable that just one study uses only quantitative methods to investigate GLOFs, while nine are qualitative and five mixed methods (Fig. 5). A similar result is shown for glacial melt and snow melt. On the other hand, quantitative methods are preferred for investigating cold/heat waves.

The treatment of risk perception and the depth of its analysis vary in the studies. When the interest is focused on the description of risk perception, mixed methods were notably preferred in the studies (64 of 157 studies, 40%), followed by quantitative (34%) and qualitative (24%) methods. The same trend was evident in relation to the study of changes in precipitation and temperature. However, this trend changes when risk perception drivers are investigated. Most studies addressing drivers used quantitative methods (28 of 72 studies), followed by mixed methods (23 studies) and finally qualitative methods (21 studies).

3.2. In-depth analysis on drivers of risk perception

3.2.1. Approaches to risk perception (in-depth analysis)

The findings show a lack of a standardised definition of 'risk perception'. There were four approaches to address this issue in the literature in the in-depth analysis (step 4, $n = 72$): two studies cited non-technical definitions of 'perception' and applied this to risk; seven studies used their own definition of 'risk perception'; 11 studies cited definitions from other scientific articles and; 52 studies included no specific definition. While this heterogeneity in usage is unsurprising when considering studies from a multitude of disciplines, it is however noteworthy that even within the DRR literature there is no absolute consensus. Furthermore, risk-related concepts (e.g. risk awareness, willingness to pay) are sometimes conflated or applied in different ways across different disciplines. This presents a considerable barrier to the coherence of future research into risk perception.

Regarding the studies' approaches to risk perception, 60 studies use the term 'risk perception' in their research question. Forty-six studies use primary data to describe risk perception, three secondary data and 18 studies a combination of both. Of these 60 studies, 55 further analyse data on risk perception, 41 connect risk perception to climate change and 58 specifically refer to natural hazards while analysing the perception of risks. Most studies identify risk perception as a cognitive process, operating not only individually, but also at the level of community and environment. At the individual level, the term is linked to beliefs, attitudes, feelings, experience and judgements, influencing both risk perception and the resulting behaviours (Ahmed et al., 2019; Bustillos Ardaya et al., 2017; Babcicky and Seebauer, 2017; Bolaños-Valencia et al., 2019; Chaturvedi and Dutt, 2015; Gravina et al., 2017; Graybill, 2013; Leiter, 2011; de Mendonca and Gullo, 2020; Nathan, 2008; Pröbstl-Haider et al., 2016; Qasim et al., 2018; Sherry et al., 2018; Yang et al., 2020).

3.2.2. Identified drivers of risk perception in mountain areas (in-depth analysis)

Results from the exploratory analysis showed that 72 studies specifically address drivers of risk perception. In the final review step (step 4, in-depth analysis), these studies were analysed to understand which drivers of risk perception are most prevalent and whether trends differ to those seen in risk perception research in general (i.e. in non-mountain environments).

Fig. 6 presents an overview of all risk perception drivers which have been addressed in the studies reviewed in step 4 ($n = 72$, multiple

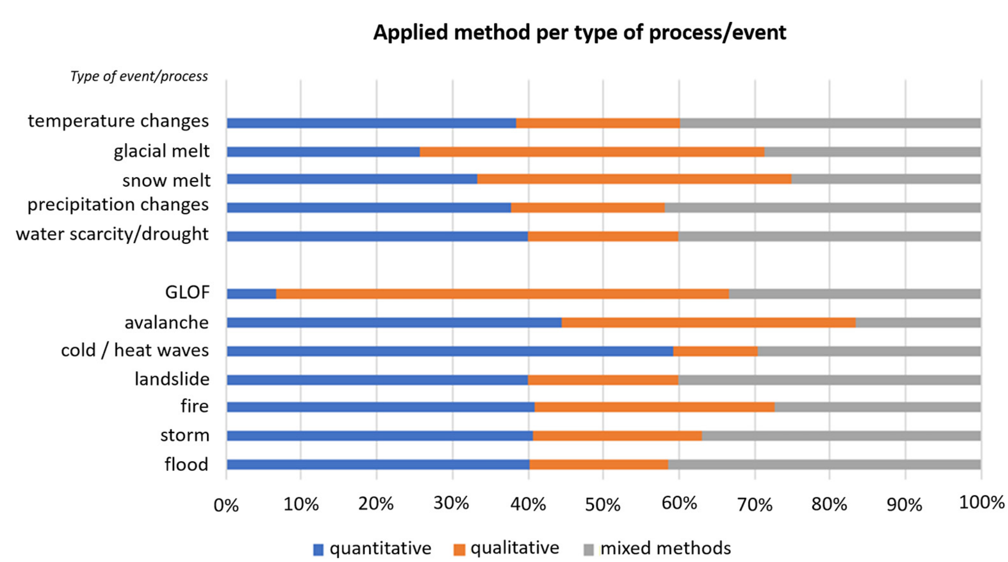

Fig. 5. Applied method (quantitative, qualitative, mixed) by type of process/event (step 3, n = 249).

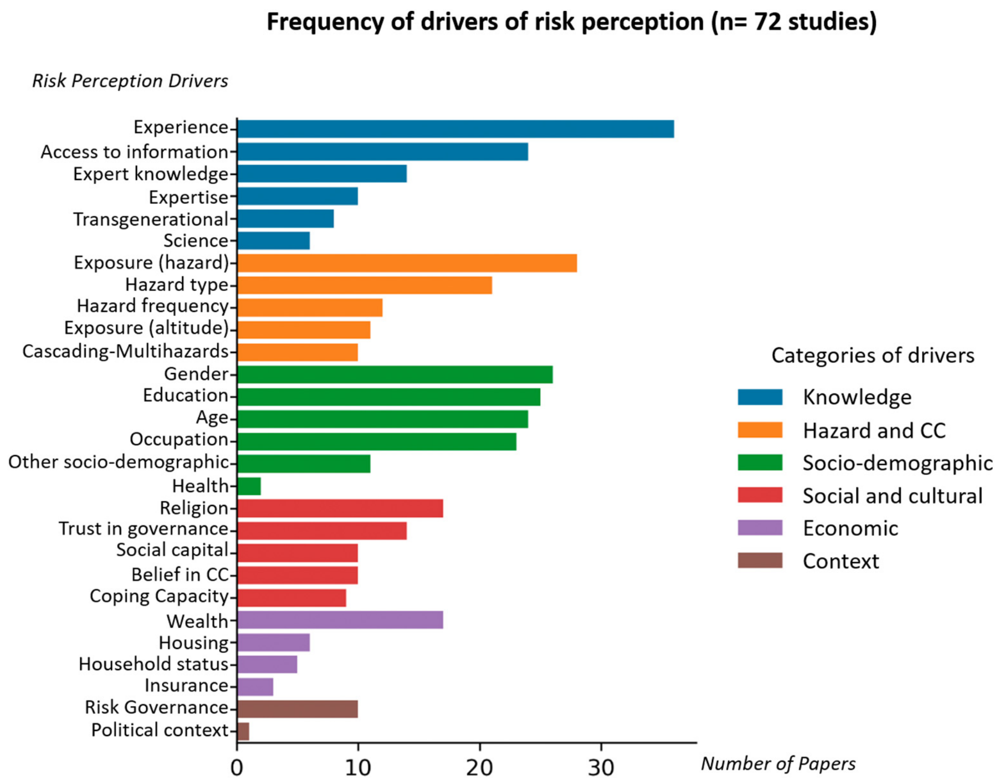

Fig. 6. Frequency of drivers of risk perception elaborated in the reviewed studies (step 4, in-depth analysis, n = 72).

entries possible). Most of these drivers touch upon aspects related to knowledge/experience, hazards and exposure or socio-demographics. The number of drivers linked to social, cultural, economic and political characteristics is significantly smaller.

Some of the drivers identified in this paper, such as *gender*, *age*, *exposure* or *experience of natural hazards*, have already been discussed in previous risk perception review studies that did not explicitly deal with mountain regions (Bubeck et al., 2012; Wachinger et al., 2013). But our review also identified drivers that have not yet been examined in the literature for their influence on risk perception. *Political context*, for example, is associated with risk perception in some studies. For example, Graybill (2013) states that "the ideology of former Soviet period still shapes the perception of relation between human, nature and technology" or Nathan (2008) who claims "lack of a history of a strong state and systems for social welfare and protection generates a different risk perception, and different security paradigms, inducing higher tolerance of risk, uncertainty and suffering in general."

Twenty-six of the 72 studies deal with the question of whether binary gender (i.e. in relation to women and men) has an influence on risk perception. However, the results of these studies do not come to a unanimous conclusion and are sometimes contradictory. Whereas some reviewed studies (e.g. Champ et al., 2013; Sujakhu et al., 2016) show no correlation between women and men; some conclude that women have a higher risk perception (Liu et al., 2018; Lujala et al., 2015; Miceli et al., 2008), in contrast to other studies (Sherpa et al., 2019; Sherry and Curtis, 2017) which conclude that women have a lower risk perception than men. Several studies have examined age as a factor in risk perception. Similar to gender, results also varied. For example, some studies found that older people were more perceptive towards climate change and related impacts and showed a higher risk perception (Ayal and Leal Filho, 2017; Reichel and Frömming, 2014; Wang and Cao, 2015) others that age is negatively related to risk perception, suggesting that risk perception decreases with age (Babcicky and Seebauer, 2017; Bolaños-Valencia et al., 2019; Champ et al., 2013; Jamshidi et al., 2018; Sherpa et al., 2019).

Other socio-demographic factors, such as personal experiences, education, income and occupation are shown to have an impact on individual risk perception, however, results also vary. Higher risk perception is linked to higher levels of education (e.g. Ayal and Leal Filho, 2017; Jamshidi et al., 2018; Liu et al., 2018; Lujala et al., 2015; Qasim et al., 2018) in some studies, but lower education in others (Barrett and Bosak, 2018; Leiter, 2011; Roder et al., 2016). Household income influences risk perception, suggesting that wealthy households tend to perceive themselves at lower risk than households with lower income (Babcicky and Seebauer, 2017; Bolaños-Valencia et al., 2019; Liu et al., 2018; Mondino et al., 2020). Occupation clearly influences risk perception to slow-onset hazardous processes linked to climate change. Farmers were subjects in 22 of 72 studies, all of which conclude that those involved in agriculture have higher perceptions of climate change (Tesfahunegn et al., 2016; Ullah et al., 2018) and are more worried about it (Barrett and Bosak, 2018). On the other hand, risk perception to fast-onset hazards is highly driven by direct personal experience of damage due to a natural-hazard event (Ayal and Leal Filho, 2017; Babcicky and Seebauer, 2017; Landeros-Mugica et al., 2016; Liu et al., 2018; Pedoth et al., 2014; Qasim et al., 2018; Roder et al., 2016; Sherpa et al., 2019). Those with personal experience are more likely to be concerned about the personal consequences of climate change (Lujala et al., 2015). Unsurprisingly, there exists a positive link between frequency of events and risk perception level (Leiter, 2011; Salvati et al., 2014), similarly a lack of any event, or events occurring far in the past, have a negative impact on risk perception (Mondino et al., 2020; Salvati et al., 2014).

A strong positive link with risk perception is given by the level of exposure to relevant risks. Studies comparing mountain with lowland areas underline the difference in risk perception of the respective populations due to their exposure to different types of processes, for example as presented by Hameso (2018) in Ethiopia. This may influence populations who decide or are forced to migrate. People can feel less secure when they leave their familiar home environments in which they are habitually exposed to potentially dangerous processes, for example when mountain people move into low altitude regions (Roder et al., 2016).

When considering mountain areas, one would expect altitude to be a key factor investigated as a driver of risk perception; surprisingly, it is only addressed in 13 of the 72 studies (Haegeli et al., 2010; Halperin, 2016; Hameso, 2018; Liao et al., 2014; Merid et al., 2017; Nathan, 2008; Pandey, 2019; Qasim et al., 2018; Roder et al., 2016; Sherpa, 2014; Sujakhu et al., 2016; Valdivia et al., 2013; Wang and Cao, 2015). Elevation (altitude) is positively correlated with climate risk perception and may also shape risk perception as climate change impacts are stronger and changes are often first evidently visible in high mountain areas. Slow-onset hazardous processes and changes reported include: the observation of changing temperatures (Hameso, 2018; Merid et al., 2017; Sherpa, 2014; Wang and Cao, 2015) and precipitation (Liao et al., 2014; Sujakhu et al., 2016; Wang and Cao, 2015), negative impact/variations on arable agriculture (Hameso, 2018; Pandey, 2019; Sujakhu et al., 2016; Wang and Cao, 2015), livestock agriculture (Liao et al., 2014; Merid et al., 2017) and, vegetation and wild fauna (Sherpa, 2014). In addition, a higher frequency of mainly water related hazards were reported, namely: floods (Merid et al., 2017; Pandey, 2019; Sherpa, 2014) or contrarily linked to water scarcity (Merid et al., 2017; Pandey, 2019; Sherpa, 2014; Sujakhu et al., 2016), but also storm (Merid et al., 2017), snow melt (Pröbstl-Haider et al., 2016; Wang and Cao, 2015), glacial melt (Wang and Cao, 2015), hail (Merid et al., 2017; Valdivia et al., 2013), changing winds (Hameso, 2018) and glacial retreat (Hameso, 2018; Sujakhu et al., 2016). One study mentions the more pronounced risk perception of mountain tourists (Pröbstl-Haider et al., 2016).

Altitude as spatial factor in shaping experience is also associated with remoteness in four studies (Miceli et al., 2008; Reichel and Frömming, 2014; Scolobig et al., 2012; Singh et al., 2017) with the idea of being in a fragile environment (Kolmodin et al., 2019; Pröbstl-Haider et al., 2016; Sherpa, 2014; Wang and Cao, 2015) and with topography (Acosta et al., 2016; Bolaños-Valencia et al., 2019; Miceli et al., 2008; Reichel and Frömming, 2014; Scolobig et al., 2012; Shrestha et al., 2019). Remoteness was also found to be linked to knowledge gaps (Pröbstl-Haider et al., 2016; Sherpa, 2014; Yang et al., 2020) or gender gaps (Scolobig et al., 2012; Singh et al., 2017). Furthermore, the experience of mountain-specific hazards such as GLOFs, avalanches and landslides/debris flows are mentioned as a driver in 14 studies (e.g. Brugger et al., 2013; Dahal and Hagelman, 2011; Leiter, 2011; Manandhar et al., 2015; de Mendonca and Gullo, 2020; Mondino et al., 2020; Pandey, 2019; Roder et al., 2016; Yang et al., 2020).

The role of religion as a driver affects risk perception both positively (e.g. increased awareness through local transmitted knowledges and a reciprocal interdependency to be fostered between human beings and the environment) and negatively (e.g. ignoring climate change as an issue, which cannot be then effectively tackled without including place-based cosmogonies/religious practices and beliefs). Out of the 72 studies, only nine studies deal with mountain specific aspects *and* religion as influencing climate change risk perception. Of these, in turn, there are only three studies that indicate a religious community as target group. However, these nine studies deal with mountain regions worldwide: in the Philippines (Acosta et al., 2016), Ethiopia (Hameso, 2018), the Andes (Scoville-Simonds, 2018; Paerregaard, 2013), Hindu Kush Himalaya (Dahal and Hagelman, 2011; Sherpa, 2014; Sherry and Curtis, 2017; Suri, 2018) and European Alps (Reichel and Frömming, 2014). This may indicate that there is a connection between religion/religious practices and climate change risk perception in mountain regions worldwide, even if further studies on this would be desirable.

In general, our review found that although there are many studies looking at drivers of risk perception in mountain areas, very few even consider mountain-specific drivers and instead look for the same drivers commonly found in the lowlands. Therefore, it is unsurprising that mountain-related drivers do not appear as important drivers. However, this represents an important research gap.

3.2.3. Relations between drivers and methodologies (in-depth analysis)

We scrutinised whether the appearance of certain risk perception drivers is correlated with a particular type of paper. Fig. 7 shows the link between the frequency of different risk perception drivers and whether the study considers risk perception in relation to hazards or to climate change, or both. Whereas overall, *experience of natural hazards* is the most commonly investigated driver from the in-depth review, this is predominantly the case in studies with a 'typically DRR approach' (Fig. 7, bottom left), that is those which link risk perception to hazards, but not to climate change. Similarly, *exposure* is the second most-investigated driver in both the DRR approach and the total sum of studies from the in-depth review. However, *occupation* - the sixth most-frequent driver in the in-depth analysis - is the most-investigated in studies which consider both hazards *and* climate change. The greatest difference concerns *belief in climate change*, which is not addressed in a single DRR paper, but which is strongly represented in studies with a link to climate change.

In light of the exploratory analysis, we hypothesised a divide between DRR and CCA approaches. This has been partially proven in the in-depth analysis: Fig. 7 also reveals that the different DRR and CCA approaches tend to focus on different subsets of drivers, steering the understanding of risk perception in different directions. While a minority of studies does not link risk perception either to disasters or to climate change (bottom right), there are major discrepancies between DRR 'only' (bottom left) and CCA 'only' approaches (top right). For example, *experience of natural hazards* and *exposure* are much more prevalent in studies which link risk perception to hazards but not to climate change, whereas *age* and *gender* are much more central to studies linking them to climate but not hazards.

Fig. 8 shows methods in relation to drivers. Purely qualitative studies tend to investigate social and cultural drivers such as religion, trust in governance and access to information and have small or very small sample sizes. Quantitative approaches tend to have larger sample sizes and investigate drivers related to hazards (*experience of natural hazards*, *exposure*) and socioeconomic characteristics (*education*, *wealth*). Meanwhile mixed methods studies tend to have neither very small nor very large sample sizes and predominantly investigate exposure and socio-demographic drivers (*gender*, *occupation*, *age*).

Quantitative approaches are more likely to have defined risk perception, implemented it in the research questions, described it with primary data and analysed data in depth. However qualitative and mixed methods studies have more often linked data to climate change, and quantitative studies to fast-onset hazards. While single-hazard studies have more often defined risk perception, implemented it in the research questions, described it with primary data and analysed data in depth, multi-hazards studies have more often linked data to climate change and to hazards. Religion and belief in climate change are drivers more prevalent in qualitative studies. Surprisingly, quantitative studies are more likely to use income, hazard exposure and governance rather than census-based data. As for mixed methods studies, they put more emphasis on demographics, expertise, previous experience, as well as hazard and disaster characteristics (*exposure*, *hazard type*, *hazard frequency*). The empirical base of studies also has an impact, with the most frequent drivers (e.g. *experience*, *exposure*, *age*) appearing in studies with medium to large sample size, while less common, harder to measure factors, such as *transgenerational knowledge*, *capacity*, or *social capital* are more often featured in studies with small (under 50 respondents) to very small (under 25) respondent base.

4. Discussion and conclusion

4.1. Discussion

It is necessary to consider how our review methodology may have influenced results. Firstly, only English language studies were

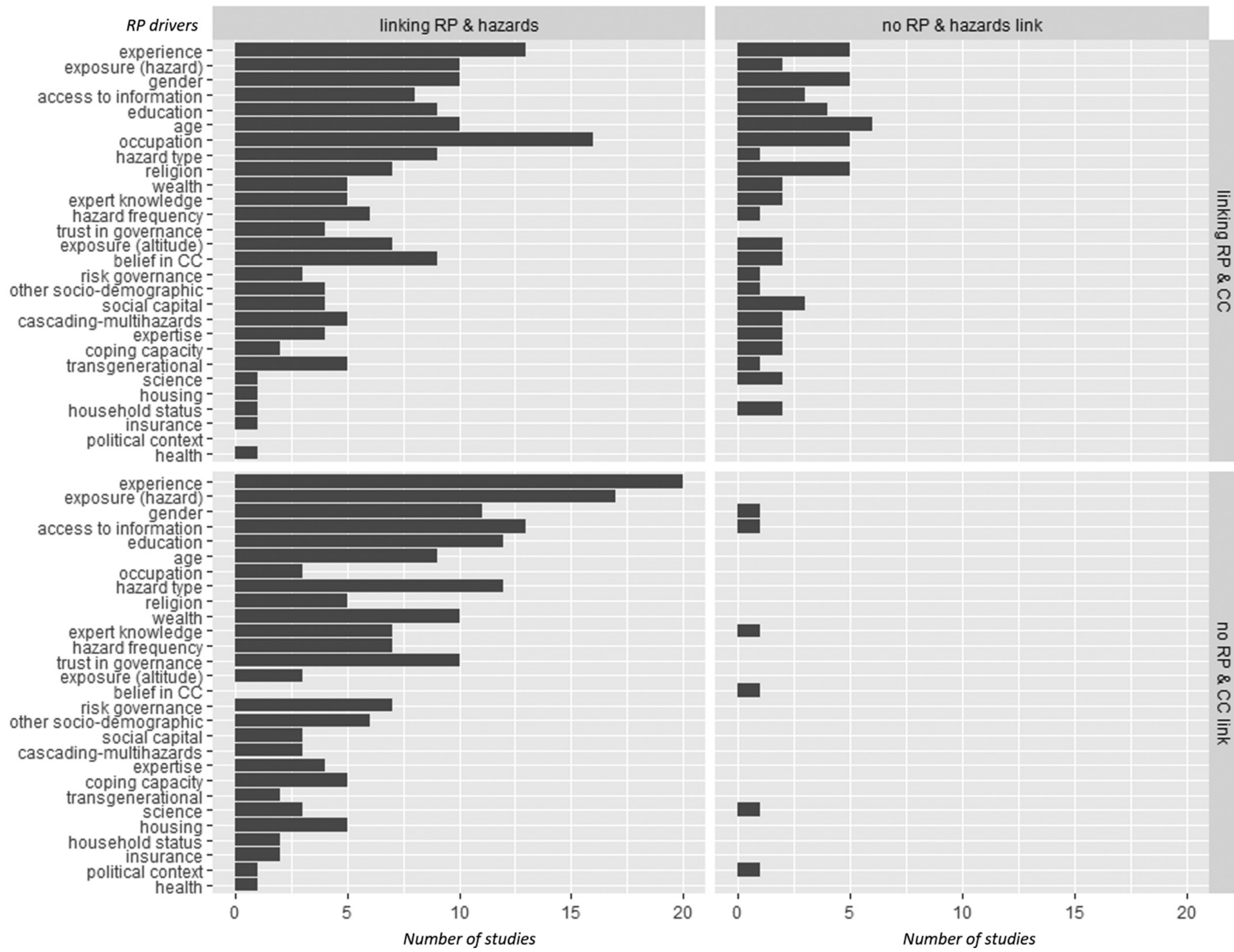

Fig. 7. Relationship between the frequency of risk perception drivers and whether study considers climate change and/or hazards in assessment of risk perception (step 4, in-depth analysis).

considered, representing an obvious bias towards research from the English-speaking world. We suspect there is a wealth of relevant studies in other languages, particularly in Spanish concerning the Andes. Secondly, humanities and social sciences are potentially underrepresented in our search. This may be due to the fact that research dealing with social, cultural and religious aspects of risk perception is alternative and/or discipline-specific journals (to which our searched databases do not subscribe) and more frequently as book chapters rather than peer-reviewed journal articles.

Keeping this in mind, our results show that there is an unbalanced geographical distribution of the studies, with a heavy focus on certain mountain ranges (such as the Hindu Kush Himalaya), and leaving other mountain ranges unrepresented (such as the Caucasus). While this may be influenced by our methodology, it also reveals the limits of the available literature.

Noteworthy is the lack of studies addressing cities and urban risks in mountain areas. Only nine out of 249 studies refer to case studies conducted in mountain cities. Those studies are mainly spread over high- and middle-income countries such as Italy (Calvello et al., 2016; Murtinho et al., 2013; Rasmussen, 2019), USA (Cholakova and Dogramadjieva, 2019) and Central or South America (Barrucand et al., 2017; Shrestha et al., 2019; Wu et al., 2015; Ye et al., 2018). The reverse conclusion is – supported by our in-depth analysis – that all our reviewed studies which touch upon low-income countries focus on rural areas and the primary economic sector. This is somewhat surprising as cities are significantly more exposed to risk due to high population density and a concentration of critical services and infrastructure. We believe that this lack of research is representative of a societal disconnect between urban spaces and their surrounding rural or 'natural' areas. These surroundings not only provide cities with ecosystem services but can also pose tremendous risk to mountain city dwellers. We therefore conclude that urban areas in mountains are under-researched and that the future increase of such risks is not represented in literature. The low number of studies that follow a longitudinal design or that question risk perception in relation to a previous event indicates a general shortcoming of research which compares risk perception situations over space or time and that identifies respective trends.

Generally speaking, modern approaches to risk perception are based primarily on theories driven by psychometric assessments and cognitive responses, either rational or affect-laden or heuristic (e.g. intuition and stigma) (Slovic, 2000). In addition, some cultural and contextualised explanations of risk perception argue for the relevance of the institutional and political structures that shape risk behaviours (Douglas and Wildavsky, 1983; Rippl, 2002). However, interdisciplinary frameworks integrating various perspectives

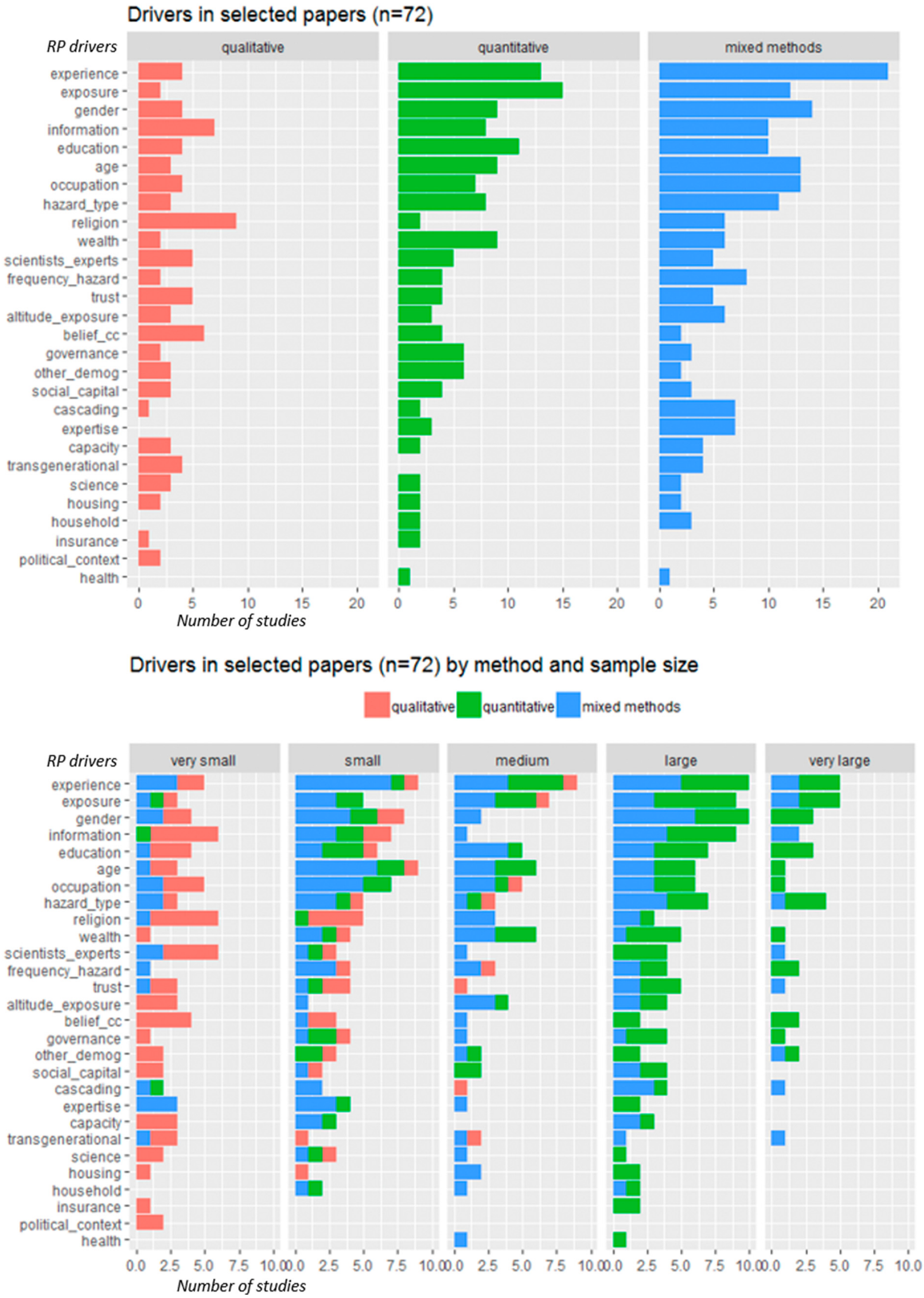

Fig. 8. Risk perception drivers by method and sample size (step 4, in-depth analysis). Sample sizes: very small sample (under 30); small (30–99); medium (99–299); large (300–999); very large (1000+). Breakdowns of the sample size categories were chosen according to the statistical distribution of sample size in risk perception studies (quantiles and then rounded for readability).

have also been proposed (Douglas and Wildavsky, 1983; Kasperson et al., 1988; Slovic, 2000; Rippl, 2002).

The results of our review reflect this diversity in possible approaches to risk perception. This heterogeneity in the understanding of what constitutes risk perception can in part be explained by the fact that to perceive (and its derivative perception) has two subtly different meanings in English: (1) Become aware of (something) using one of the senses, especially that of sight and; (2) Interpret or regard (someone or something) in a particular way (Oxford Dictionary of English 2020, perceive entry). Accordingly, in a number of studies, the perception of climate related risks is essentially understood as climate risk awareness. Consequently, most of these studies focus on a mere description of 'risk perception' rather than investigating its influencing drivers.

Several studies investigate human perceptions with the aim of observing and monitoring changes in climate conditions. In these cases, mountain communities and their climate risk 'perception' replace missing sensors in remote areas where the distribution of weather and climate stations is scarce. That is, human perceptions (as in observations) become a proxy that supports or validates instrumental climate/environmental data when the latter are unavailable, of low quality, not existing in sufficient time series and/or only collected on recent periods (Aryal et al., 2016; Boissière et al., 2013; Carothers et al., 2014; Cholakova and Dogramadjieva, 2019; Esayas et al., 2019; Kahsay et al., 2019; Kavianpoor et al., 2019; Kieslinger et al., 2019; Konchar et al., 2015; Lamsal et al., 2017; López et al., 2017; Luitel et al., 2019; Macchi et al., 2015; Manandhar et al., 2015; Meena et al., 2019 Shukla et al., 2019; Spies, 2020; Tran et al., 2010; Vedwan and Rhoades, 2001; Venable et al., 2012; Wangchuk and Wangdi, 2018).

Our review reveals a certain degree of separation between (i) studies dealing explicitly with climate related risks of slow-onset changes (such as temperature rise or water scarcity) and how people perceive these long-term changes and (ii) studies dealing with fast-onset hazardous events such as floods, landslides or GLOFs, which mostly only refer implicitly and indirectly to changing climate conditions. The former of these studies predominantly deals with impacts on the agricultural and natural environments such as crops and forests as well as related consequences for farmers and shepherds. The latter focuses on potential damages to the built environment, critical infrastructure and human populations as well as related damages. We hypothesise that the authors of studies in the former category (slow-onset hazards) are stronger linked to the scientific community of CCA, with authors of the latter category (fast-onset hazards) tend to come from the field of DRR. This is concerning given the obvious and urgent need for a convergence of both approaches which is expressed and requested at all levels (most prominently by the United Nations through its Global Assessment Report (GAR) 2015 (UNDRR, 2015) or its recently published paper Integrating Disaster Risk Reduction and Climate Change Adaptation in the UN Sustainable Development Cooperation Framework (UNDRR, 2020).

Moreover, DRR and CCA approaches tend to base their work on a different terminology. In many studies, 'risk perception' is intended as climate risk awareness (e.g. Abrha and Simhadri, 2015; Ayal and Leal Filho, 2017; Byg and Salick, 2009; Chaudhary et al., 2011; He and Richards, 2015; La Frenierre and Mark, 2017; Mark et al., 2017). As a result, the common use of 'perception' might be misleading, giving on the surface the appearance of a much greater convergence between CCA and DRR studies than the actual research questions and operations actually demonstrate. This might also be one of the shortcomings of any keyword approach, assuming a greater convergence due to similar mentions when their varying meanings are buried under the minutiae of their concrete uses. Consequently, the research gap on risk perceptions and behavioural change among mountain communities as well as local knowledge co-production and inclusivity is even greater than the overall number of studies would have suggested, especially that which concerns indigenous voices (Ford et al., 2016) and communities estranged from the process of knowledge production (Klenk et al., 2017).

In line with existing general risk perception literature (Altarawneh et al., 2018; Wachinger et al., 2013), most studies identify risk perception as a cognitive process, operating not only individually, but also at the level of community and environment. At the individual level, the term is linked to beliefs, attitudes, feelings, experience and judgements, influencing both risk perception and the resulting behaviours (Ahmed et al., 2019; Babcicky and Seebauer, 2017; Bolaños-Valencia et al., 2019; Bustillos Ardaya et al., 2017; Chaturvedi and Dutt, 2015; Gravina et al., 2017; Graybill, 2013; Leiter, 2011; de Mendonca and Gullo, 2020; Nathan, 2008; Pröbstl-Haider et al., 2016; Qasim et al., 2018; Sherry et al., 2018; Yang et al., 2020). Together with the associated religious understandings of nature, which prevails in many parts of the world, this leads to a strong cultural aspect to risk perception (Paerregaard, 2013; Scoville-Simonds, 2018; Sherry et al., 2018). An indigenous understanding and interpretation of changes and events involves the interrelation of nature, culture and religion. While religion, on the one hand, was understood in some studies as a factor that has little impact on the perception of climate change risk (e.g. van der Linden et al., 2017), other studies defined religion as a crucial factor in perceiving and understanding risks and related hazards (e.g. Mitchell, 2000; Sun and Han, 2018). In particular, various indigenous communities maintain traditional interpretations of risks and disasters as supernatural punishment resulting from weakened religious practices and the loss of traditional values (Acosta et al., 2016; Merid et al., 2017; Scoville-Simonds, 2018; Suri, 2018). We expected this to be particularly reflected in the literature on mountain studies since many of the reviewed studies research rural and remote areas. However, only 17 studies mention religion as a driver, including religious belief systems, religious awareness, answers and approaches towards risk perception. Similarly underrepresented are the aspects of place attachment and identity, which is surprising given the wide range of existing literature in non-mountain environments which focuses on these aspects.

Importantly, only nine studies in the in-depth analysis explicitly include references to indigenous knowledge (Acosta et al., 2016; Ahmed et al., 2019; Córdova et al., 2019; Graybill, 2013; Hameso, 2018; Nathan, 2008; Paerregaard, 2013; Roder et al., 2016; Scoville-Simonds, 2018) despite the importance of this type of perception through cultural lenses already having been emphasised (Ford et al., 2016; Klenk et al., 2017; Yeh, 2016). The inclusion of such information is of course associated with an added complexity in the scientific processing and the merging of results from other methods. Its inclusion is also hindered by the strong place and culturally specific nature of indigenous knowledge for which Western ontological systems cannot satisfactorily account (Amin, 2010; Gergan, 2017; Said, 1978; Yeh, 2016). The result is that various studies often overlook or oversimplify the understanding of risk perception of indigenous communities (Klenk et al., 2017). When indigenous and Western knowledge are integrated, the results may even contradict each other at first glance (Nightingale, 2016). Nevertheless, this diversity in the understanding of phenomena and risk perception must be considered in tailored policy making. In this context, it should also be taken into account that multiple understandings of terminology are possible, that some concepts cannot be translated across cultures and that the world views of western scientists and local people can occasionally clash (Paerregaard, 2013; Yeh, 2016). For example, climate change is not only perceived as a natural phenomenon by mountain peoples but also as plurality and/or as a part of cyclic life, whereby different religious ideas and cultural differences influence the respective views and thus also the understanding and perception of natural phenomena. However, colonial and neocolonial patterns, including a colonial and neocolonial understanding of environment, a hierarchy of knowledge and a reproduction of Eurocentrism, have marginalised local peoples who have had little involvement in decision-making, even if those decisions affect their daily lives (Davis et al., 2020; Tucker, 2018). One result of this marginalisation is the overlooking in research of important risk perception drivers that are tied into local knowledge.

A major part of our work concentrated on the drivers of risk perception identified within the studies and possible correlations of such drivers, or clusters of them, with other characteristics of the reviewed work. Most of the drivers that appeared in the reviewed studies also appear in the existing literature on risk perception in general. Although we have narrowed down the scope for risk perception studies by means of our mountain focus, there is no apparent increased consensus concerning the influence of certain drivers compared to this general literature. That is, studies in our review differ in their findings with regards to the role that certain drivers such as gender or age play for risk perception. Other drivers, such as experience, frequency of hazards or exposure are considered positively correlated to risk perception throughout most of the studies. A number of drivers investigated have not been scrutinised very often in previous reviews such as those relating to the political context, or religious community and cultural aspects despite their significance having been pointed out by a number of authors, to name only a few examples Wisner et al. (2003) and Taylor (2014). This may hint to a recent, stronger research focus on such intangible factors.

The heterogeneity of approaches to risk perception and the different methodological approaches employed also influence the reported risk perception drivers. Our results reveal that the different DRR and CCA approaches tend to focus on different subsets of drivers, steering the understanding of risk perception in different directions. Moreover, there is a difference between those risks investigated in the studies selected for the exploratory analysis (step 3), and the refined study selection investigating risk perception drivers (in-depth analysis, step 4). The focus on water scarcity of the former is replaced by a focus on landslides and floods in the latter. This suggests that a significant number of studies that deal with floods and landslides are more often investigating related risk perception drivers than those that deal with water scarcity.

Considering all reviewed research is conducted in mountain areas and, given the fact that several studies mention that risk perception in mountains differ from that in the lowlands, there are surprisingly few drivers investigated that are unique or specific to the mountain environment. We assume that this is due to research approaches which in their design do not consider the possibility of mountain-specific drivers. Instead many authors investigate drivers most commonly found in broader risk perception literature. This reinforces a bias towards drivers that are universal to all environments, for example, experience, exposure and socio-demographic characteristics, and hence may not be able to capture other critical but often context-specific factors of risk perception.

One reason for the neglect of certain drivers may be that some crucial issues (i.e. religion, trust in governance, social capital, coping capacity, risk governance context and political context) are usually more complex than other drivers and are more challenging to measure, categorise, analyse and contextualise. Consequently, it may require considerably more time to correctly understand and analyse the individual levels and the entire scope of the more intangible drivers, which is why they have not received as much research attention thus far.

4.2. Conclusion

There is little information to be found in the literature which would shed light on the specific situation of risk perception in mountain areas and the influence of risk perception on adaptive behaviour. Important aspects characterising mountain communities such as place-attachment or the role of religion for the determination of risk perception are barely considered in any paper. Furthermore, very few studies acknowledge a role for local knowledge in the understanding of risk perception, reflecting a wider issue of the hegemony of Western science in knowledge creation and governance in areas where worldviews may differ greatly. Therefore, there is a strong need for the intensification of research on risk perception in mountain regions, which should investigate to what extent mountain-specific aspects (in the wider sense, be it bio-physical, economic, social or cultural) are significant explanatory factors in risk perception. Interdisciplinarity is essential to comprehend the diversity and interactions of multitudinous drivers.

Our review hints at a number of research and knowledge gaps which have an influence on the design of climate risk mitigation and adaptation measures and the approaches required to implement them, including:

- There is a geographical focus of studies on certain mountain areas, others, such as in Central Asia or the Caucasus, are under-represented.
- The significance of urban areas as well as population agglomerations in mountain regions and related risks are not sufficiently considered.
- There is very little research comparing risk perception characteristics over space and time. More longitudinal studies are needed as well as research comparing different communities in the same mountain range, communities from different mountain areas worldwide but also communities from highlands and lowlands.
- There is (still) a certain divide between the scientific communities of Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR). More research reflecting the connections between risk perception of climate change and natural hazard risk management and a more integrated view of both slow-onset changes of climate parameters and fast-onset hazards such as floods or landslides is necessary.
- The scope of the current major search systems does not favour true multidisciplinarity in systematic literature reviews since too few publications from social sciences and humanities are included in their databases. We therefore urge either for the creation of an interdisciplinary platform that can facilitate such a review or the inclusion of a broader range of disciplines and publication types in established search systems such as the ones used for this review. Research that analyses risk perception in mountain regions should go beyond a description of risk awareness and should consider mountain specific drivers, ideally taking into account crucial aspects of the religious, social, cultural and political settings.
- These are significant research gaps since mountain people's risk perceptions, and importantly its influence on adaptive behaviour, need to be better understood in order to inform policy which will protect the vital mountain ecosystems and the societies that depend on them.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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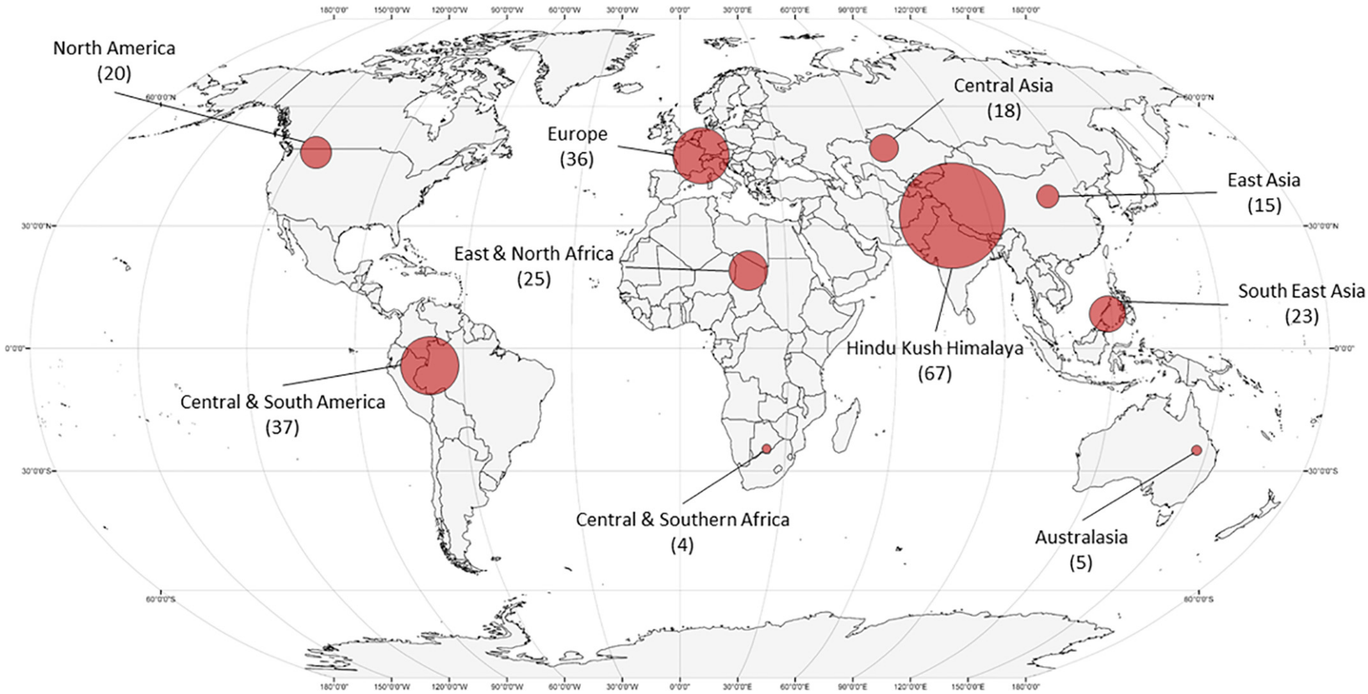
Appendix A



Appendix 1. Global distribution of case studies across mountain regions (number of case studies from selected studies [step 3, exploratory analysis]) – double entries possible.

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