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Stakeholder Perceptions of Nature-Based Solutions and Their Collaborative Co-Design and Implementation Processes in Rural Mountain Areas—A Case Study From PHUSICOS

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Planners and engineers increasingly discovered nature as a source of inspiration to mitigate hydro-meteorological risks resulting from extreme weather events. Actors are realizing advantages of such solutions known as Nature-Based Solutions (NBS) to rapidly adapt to changing climate patterns and related impacts such as flooding, landslides, mudflows or rockfalls. NBS also provide multiple co-benefits such as an increased landscape value for society and biodiversity. Because of their inherent characteristics, NBS implementation are more efficient when supported by participative approaches. At the same time, strengthening democratic and collaborative planning into Living Labs approaches generates an increase in interest. This helps to overcome bottlenecks when implementing measures and provide common ground to provide space for new ideas, to promote innovation and to develop solutions with high acceptance. While co-design and implementing NBS has already been applied and well documented for urban areas, there are few publications on collaborative planning, stakeholder perception and NBS co-implementation in rural mountain areas. In our case study analysis from the EU-funded H2020 project PUSICOS, we present stakeholder views on NBS, their possibility to reduce natural hazards in different mountainous case study areas, different discussed measures, NBS types and stages of implementation. We analyze expectations on Living Lab processes to co-design NBS and important topics to be addressed in these processes from the view, perspective and perception of local stakeholders. Despite the importance of NBS on political and research agenda, in both the literature and the interviews, the concept and ideas are less familiar to stakeholders. NBS are mainly encountered within river restoration measures. The main interest was to reduce risks and to find solutions that were attractive and interesting also from an economical point of view e.g. business models for farmers and landowners and less of the multiple benefits

that are most important for stakeholders in urban areas. The collaborative planning approach was seen as important for engaging stakeholders and creating knowledge about NBS. These insights will contribute to the understanding and address the management of intense stakeholder involvement processes, identify barriers that arise, and support in-depth participatory processes.

Keywords: Nature-Based Solutions, stakeholders, living Labs, stakeholder perspectives, perception, Acceptance, collaborative planning

1 INTRODUCTION

Climate change causes the increase of extreme hydro-meteorological events triggering floods, landslides, mudflows, avalanches or rockfalls (Kumar et al., 2020). Nature-Based solutions (NBS) are increasingly considered as suitable, viable solutions to increase the effectiveness of technical solutions. For example, they can partially or fully replace static flood protection infrastructures or reduce exposure or vulnerability for landslides, avalanches and rockfall, reduce negative impacts by drought or heatwaves (European Commission—Directorate-General for Research and Innovation, 2015). NBS received a lot of attention in recent years, even reaching the top of both political and research agendas (Nesshöver et al., 2017; Frantzeskaki et al., 2019). The European Union defines NBS as “Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes through locally adapted, resource-efficient and systemic interventions. Nature-based solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services” (European Commission—Directorate-General for Research and Innovation, 2015). The IUCN describes NBS as “Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et al., 2016). Examples given by the IUCN are restoring and sustainably managing wetlands, conserving forests, restoring drylands, developing green infrastructure in urban environments and using natural coastal infrastructure with a multitude of benefits for mitigating, and adapting to climate change, enhancing biodiversity but also linking these benefits to the targets of the sustainable development goals such as food security, economic development, education and health benefits (Cohen-Shacham et al., 2016). NBS can be considered as an “umbrella term” for these wider range of concepts and practices (Nesshöver et al., 2017; Pauleit et al., 2017). Benefits of NBS are seen in both providing increased resilience and multiple co-benefits such as increased landscape values for society and biodiversity (Cohen-Shacham et al., 2016; Raymond et al., 2017). The European Union also indicates that NBS can be a source of innovation, with possibilities to deliver multiple benefits across different social groups in a range of environmental, economic and cultural settings and address the challenges of changing climate. The

Paris Agreement signatories explicitly refer to NBS to help achieve the mitigation of climate change and as a key adaptation strategy. Mainstreaming NBS is also a core aim in global agendas to deliver on the Sustainable Development Goals (Martin et al., 2021).

While NBS have received a lot of attention in urban areas, this is not the case for rural mountain areas. With their greater exposure to risk and vulnerability to climate change, NBS not only reduce risk to the local population but can also reduce accumulating small events and prevent them from becoming large-scale disasters in densely populated areas downstream (Solheim et al., 2021). PHUSICOS intends to demonstrate the effectiveness of NBS and their ability to reduce the impacts of extreme hydro-meteorological events in rural mountain landscapes. PHUSICOS works on a broad range of NBS addressing hydrometeorological risks across the different case sites. Potential solutions address flooding and water storage/retention, rockfalls, avalanches, landslides, water quality and runoff from agricultural areas, river restoration and novelty NBS to stabilize mountain slopes. An important aspect of PHUSICOS is the upscaling potential of the measures to be implemented.

However, the number of implemented NBS is still low. Unsupportive governance (Kabisch et al., 2016; Ershad Sarabi et al., 2019), various barriers such as lack of political commitment (Solheim et al., 2021) and missing inter-sectorial communication (Zingraff-Hamed et al., 2020a) slow down or halt their implementation. One key success factor to overcoming bottlenecks resulting from a lack of cooperation is in-depth stakeholder involvement right from the beginning. Intense collaborative planning among different public and private actors, as well as citizens for the design and implementation of solutions from the initial stages is recognized as an efficient tool to solve complex problems and to find innovative designs. Recent studies identified that such partnerships and collaborative approaches are crucial for successfully implementing NBS (e.g. Zingraff-Hamed et al., 2021) and creating acceptance, sense of ownership and ultimately, the success of measures and their implementation (Lupp et al., 2021). It is therefore important to involve all relevant stakeholders to ensure a well-functioning co-design process and to deal with potential conflicts, issues, and constraints that may arise (Zingraff-Hamed et al., 2020b). Formalized procedures for collaboration and participation are vital to support the design and implementation of solutions (National Research Council, 2008), and they are increasingly becoming mandatory in projects (Scolobig et al., 2016). Identifying and addressing stakeholder values, interests, and

knowledge is a crucial first step for such collaborative processes (Burgers and Farida, 2017). Especially, understanding their skepticism and how to motivate them to act is important to orchestrate collaborative planning (Lupp et al., 2016).

Thus it is important to know how different stakeholders perceive hazards and potential NBS solutions. NBS often require integrated measures which implies collaboration and the willingness of stakeholders to act (Heitz et al., 2009). According to Heitz et al. (2009), risk perception and striving to implement solutions is based on own experiences, beliefs, and psychological, social, economic, temporal or institutional factors. A number of theoretical approaches exist to describe perception of risks, behaviors and actions. Mañez et al. (2016) extend a model of risk perception as a stepping stone for taking actions based on cultural backgrounds, socio-political factors and cognitive affective factors that are influenced by individual and collective backgrounds. Pagliacci et al. (2020) outline the varieties of rationalist and constructivist approaches with the Protection Motivation Theory and Protective Actions Decision Model being the most frequently applied. They are rooted in Planned Behavior theories and consider subjective norms, attitudes, perceived behavioral control and background factors influencing decisions triggering action. Venkataramanan et al. (2020) highlight the willingness to make changes depending on a variety of factors such as awareness of the problem, knowledge, attitudes, intentions that lead to implementing or adopting solutions.

However, stakeholder involvement and perceptions are quite frequently examined from a theoretical point of view in the literature. Actual stakeholder views on NBS are far less frequently explored. For mainstreaming and upscaling of NBS and creating acceptance and a perception among stakeholders that NBS are a suitable and desirable solution, a key aspect is the evolution of the perception and awareness of NBS in such collaborative processes. This aspect is largely missing in literature.

The objective of this paper is to give preliminary insights into the stakeholder perspective of the ongoing collaborative planning and design processes in PHUSICOS. It intends to give insights into stakeholder views and perceptions, awareness and expectations of NBS in the collaborative processes, and the role of engagement and collaborative processes surrounding NBS. It will provide an initial outlook on aspects that are important to raising awareness and improving the perception of NBS as desirable solutions for different stakeholders.

The main research questions are:

- What are the perceptions of NBS or neighboring concepts?
- What are the main interests and concerns of such solutions? Are there differences between urban and rural mountain settings?
- What expectations do actors have regarding collaborative planning of NBS?

The paper presents initial results from the PHUSICOS project and provides insights from the beginning of an intensive in-depth collaborative planning process using Living Lab approaches as systematic, theoretic, and formalized approaches for collaborative

planning and co-designing processes (Fohlmeister et al., 2018). With a variety of applications and approaches, Living Labs can be seen as a methodology, system concept, or an environment. The key elements are openness, knowledge development, learning processes for all participants, and meeting on equal ground, including the ones initiating such a process. Other key elements are putting the ones that are affected in the center of the processes and focusing on collaboration with stakeholder involvement right from the beginning to form a quadruple helix innovation network to engage end users (e.g. citizens, NGOs), the public sector (administrations, policymakers), the private sector (businesses) and academia (Lupp et al., 2021).

To provide initial outcomes of the collaborative processes at the different case sites in the coming years, stakeholders will be interviewed continuously with different methodological approaches to assess their perspectives on NBS, learning processes, expectations towards NBS, collaborative planning and co-design, and lessons learned from the collaborative work. For collaborative planning, PHUSICOS applies a Living Lab concept to support and institutionalize intensive collaboration of stakeholders for the co-creation, co-design and co-monitoring of NBS. Despite some fuzziness resulting from a wide variety of activities carried out under the umbrella term “Living Labs”, this concept provides a systematic approach and a framework for stakeholder engagement to provide guidance through different phases of the NBS co-creation processes. A quadruple helix network is in the center of the co-creation process engages stakeholders from the private sector, end users such as citizens and their representatives, the public sector like administrations and academia meeting on equal grounds (Fohlmeister et al., 2018; Lupp et al., 2021).

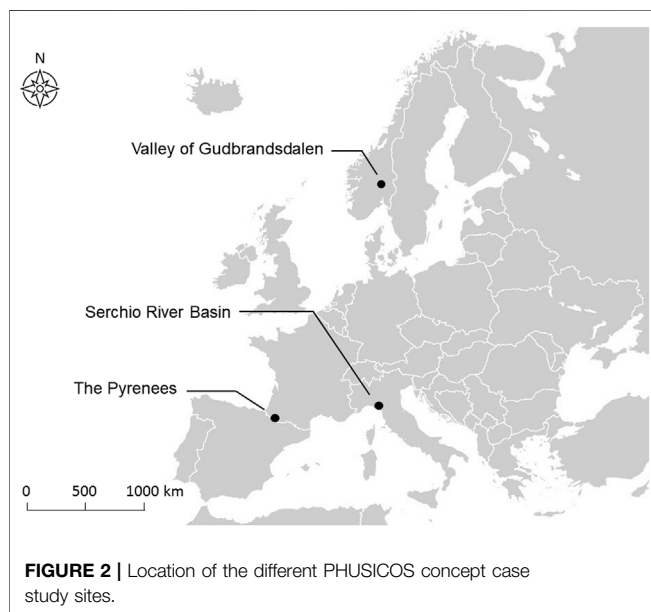
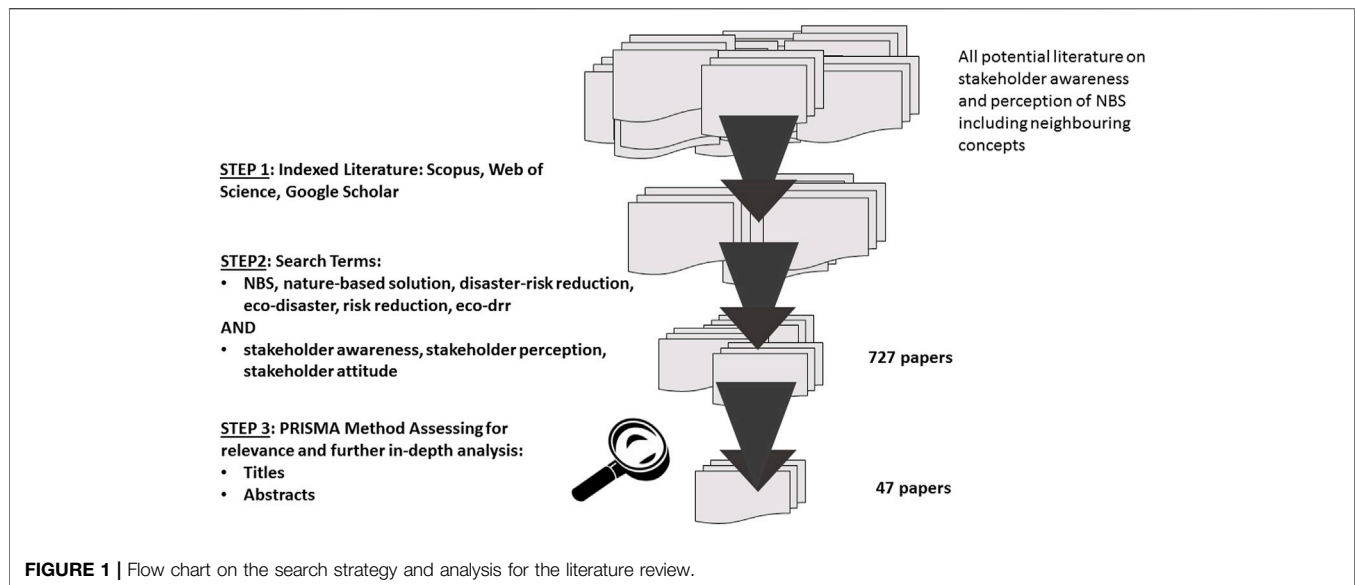
2 MATERIALS AND METHODS

2.1 Literature Review

With the growing popularity of NBS, the number of terms used to describe or conceptualize them has seen an explosive increase. Therefore, we realize our literature review cannot be exhaustive to include the abundance of all terms and all literature that exist such as reports or presentations that currently exist and opted for the following search strategy (also **Figure 1**).

First, we conducted a literature review between February 10 and 23, 2021 using the Web of Science, Scopus and Google Scholar databases with key search terms that were relevant to stakeholder perceptions of nature-based solutions. It was considered important to use more than one database since search algorithms may vary across databases. In this case, each database yielded a few unique publications which the other databases did not find. We first searched from all three databases with the search terms: (sustainable drainage OR NBS OR nature-based solution OR disaster-risk reduction OR eco-disaster risk reduction OR eco-drr) AND (stakeholder awareness OR stakeholder perception OR stakeholder attitude).

We also used some terms on neighboring concepts of NBS to collect work on stakeholder perspectives from these fields that



promote a similar intention: more natural or nature-inspired solutions to reduce risks, exposure and vulnerability of natural hazards triggered by hydrometeorological events.

A total number of 727 papers were identified. We utilized the PRISMA method (Moher et al., 2009) to identify the most relevant papers. First, we assessed the titles of these papers for relevance and categorized them based on relevance. Then, we assessed the abstracts of the papers with the most relevant titles to further determine which papers would be useful for our research. In this way, we identified 49 relevant publications. We then reviewed the content and extracted the relevant information to be incorporated into our research for a qualitative content analysis (Mayring, 2000).

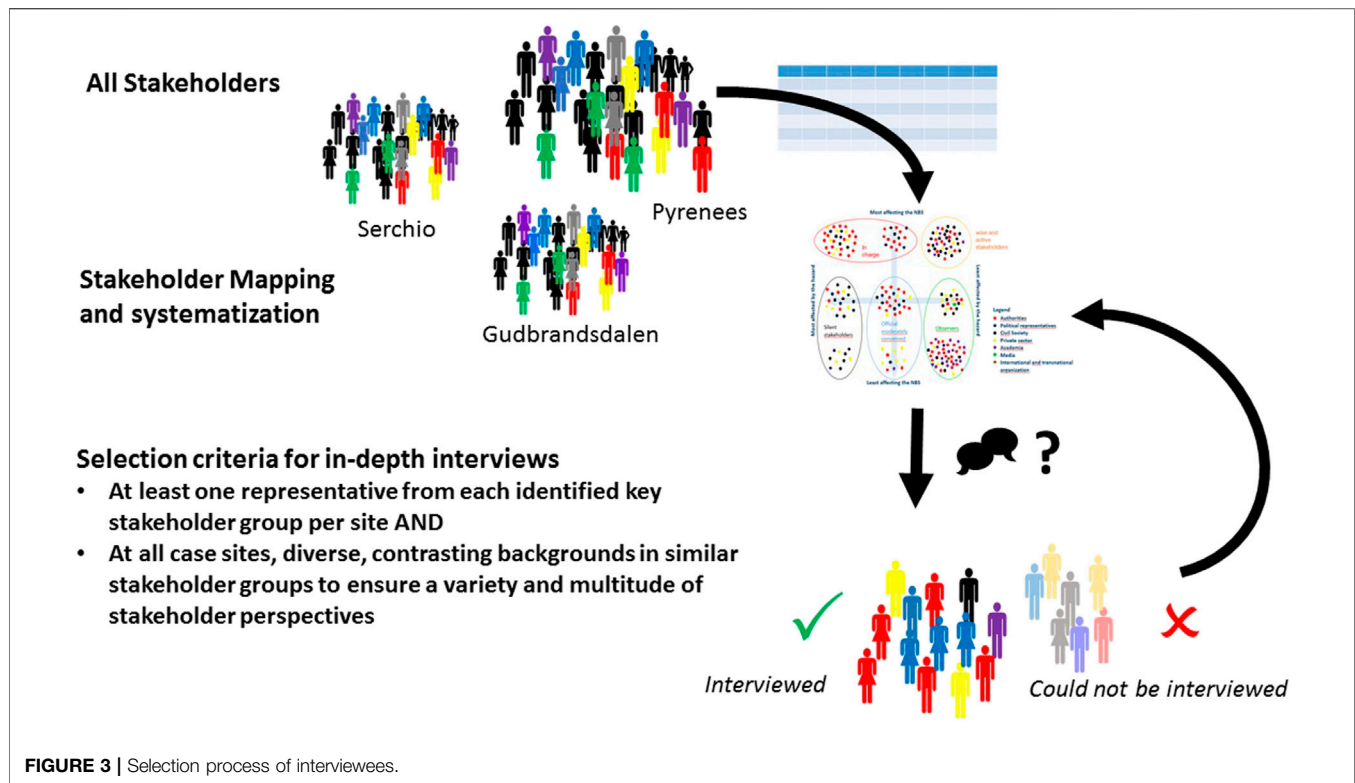
2.2 Case Study Approach

A case study approach is seen as a flexible way for in-depth investigations at small scales that balance breadth and depth (Taylor, 2016). The studies chosen are the three PHUSICOS demonstrator sites for developing and implementing NBS for reducing the risk from natural hazards in rural mountain areas. The demonstrator case sites are located in the valley of Gudbrandsdalen, Norway, in the Pyrenees, France and Spain, and in the Serchio River Basin, Italy (Figure 2).

The *Valley of Gudbrandsdalen* is 140 km long and one of the most populated valleys in Norway. It extends from the village of Dombås in the north to Lillehammer in the south. The river valley is extensively used as farmland. Many settlements are located close to the river. The area is exposed to a range of hydro-meteorological hazards such as flooding of the main river and its tributaries, debris flows and debris slides, rockfalls and snow avalanches. Potential measures to address these issues are the reestablishment of floodplains and enhancement of the water storage capacity in the catchment areas (PHUSICOS, 2021).

In the *Pyrenees*, a mountain range between France, Andorra and Spain, reforestation can help to cope with hydro-meteorological extreme events by reducing the hazard intensity. Afforestation in the release areas can reduce the risk of avalanches. For reducing hazards arising from rockfalls and debris, reshaping a slope through terracing techniques to support with the establishment of vegetation to stabilize the sediments have already been successfully applied a century ago and serve as an inspiration for new measures in the region (PHUSICOS, 2021).

The *Serchio River Basin* in Tuscany, Italy is of national interest according to Italian law and has been identified as a “river basin district” for implementation of EU’s Water Framework Directive. A combination of challenges include extreme drought and flooding, seismic risk as well as water pollution by runoff of sediment and nutrients from adjacent farmland. The set of proposed measures include re-vegetation efforts and farming practices to stabilize the soil and to reduce the



runoff from the agricultural fields to the water bodies and Lake Massaciuccoli (PHUSICOS, 2021).

For these demonstrator cases, various stakeholders are actively involved throughout the project using living labs in order to incorporate their knowledge, preferences, views, values and attitudes. One of the main goals of the project is to involve and motivate stakeholders to shape and co-design the implementation of NBS.

2.3 Qualitative In-Depth Interviews

To assess the stakeholder perspectives on NBS, the in-depth participatory processes and in-depth collaborative planning approaches by using a Living Labs approach, we opted for a qualitative approach (Atteslander, 2003). A comparatively small group of interviewees were used in this approach to collect in-depth understanding with semi-structured protocol interviews being developed for this purpose (Marshall and Rossman, 1998).

To cover different perspectives, attitudes and opinions, a systematic approach to select interview partners was chosen according to the principle of maximum contrasts based on the grounded theory (Strauss and Corbin, 1990). The aim was to cover a wide range of perspectives within a small group of interviewees. Criteria could be differences in sociodemographic characteristics, different professional backgrounds and different opinions. Recruiting interview partners followed the following approach (also **Figure 3**).

In considering PHUSICOS's different sites and to allow cross-site comparisons, first, a systematic stakeholder identification task was conducted following an approach developed by the

PHUSICOS's sister project RECONNECT (Hüesker et al., 2019). Based on systematic stakeholder mapping described by Zingraff-Hamed et al. (2020b), potential stakeholders were listed based on available information from the different sites and on their documentation and available protocols from initial stakeholders meetings within the PHUSICOS project. Based on this information, a list of stakeholders was compiled and assigned to a stakeholder group. The local facilitator teams in charge of the stakeholder processes were asked to add more potentially relevant stakeholders, for example by replacing those not responding to their invitations, unwilling to participate or relevant only for a single or certain steps during later stages of the collaborative planning and co-creation process (Lynam et al., 2007; Reed et al., 2009). Based on the concept of interest-influence matrices and three-dimensional power-influence-attitude grids (Murray-Webster and Simon, 2006), local facilitators were asked to evaluate the roles of stakeholders as well as their importance in the different co-design, co-implementation and co-monitoring/evaluation stages, their relation and affectedness by natural hazards, NBS and decision processes on finding potential solutions to reduce natural hazards.

Based on the results of the stakeholder mapping, interview partners at the different sites were selected for an interview in an iterative process. At each site, at least one representative from the commercial sector, academia, authorities, political representatives and from civil society (represented e.g., by NGOs) would be part of the interview panel. Across all case sites, different backgrounds and sociodemographic features to provide potentially very differing views, perspectives and

backgrounds of the interviewees were considered according to Hunziker (2000) to encompass a broad range of perspectives.

However, not all of the initially identified persons (around 20) could be interviewed and other persons had to be chosen instead. Some refused the request for an interview or were unavailable in the given timeframe. Also, some potential interview partners were difficult to reach during the COVID-19 pandemic, and approaches such as collecting interviews in suitable, good environments for building trust for exchange that are important for such qualitative interview approaches (Elwood and Martin, 2000), were difficult to realize. This might have led to a lack of willingness to participate at an early stage of the collaborative processes as well.

Interviews were conducted by phone or video-calls. Notes were taken when interviewees rejected to be recorded. Recorded interviews were transcribed and translated to English for the assessment. The texts were then analyzed, shortened and structured to highlight the key statements and relative frequencies according to Mayring (2000) and Mayring and Brunner (2010).

3 RESULTS AND DISCUSSION

3.1 Key Findings From the Literature Review and Discussion

3.1.1 Nature-Based Solutions, Neighboring Concepts and Stakeholder Perspectives

Despite the broad scope of the literature search including neighboring concepts and disaster risk reduction, not much work on stakeholder perceptions on strategies to reduce risk with NBS or similar concepts could be found. Interestingly, disaster risk reduction, similar concepts and stakeholder perspectives mainly relate to understanding their perception of natural hazards, risks, vulnerability and preparedness to react to an occurring disaster, e.g. evacuation. Related to disaster risk reduction, there is not much mentioned about measures to reduce the risks, or exposure of natural hazards. Buchecker et al. (2013) state in their work that risk perception approaches in literature with a spotlight on disaster risk reduction have a strong theoretical nature and often focus on the perception of risks rather than the perception of risk prevention measures.

Han and Kuhlicke (2019) scanned 1834 NBS papers for stakeholder perspectives and perceptions of NBS in literature but only found 15 papers addressing how people value and perceive the co-benefits of NBS and related concepts. Ferreira et al., 2020 conducted a systematic literature review on NBS with a focus on urban areas related to establishment of green infrastructure (GI) and sibling concepts and came up with 142 papers on stakeholder perspectives. Piacentini and Rossetto (2020) analyzed stakeholders in water related NBS and GI which were almost all situated in urban and peri-urban areas in Mediterranean France and Italy. They found little interest and response from rural areas on these concepts and rather low awareness of concepts of water-related NBS.

3.1.2 Knowledge About Nature-Based Solutions Concepts

Bark et al. (2021) described in their study from the United Kingdom on Natural Flood Management (NFM), that two-thirds of the respondents considered themselves familiar with NFM, however, only 8 strongly considered themselves experts. Understanding and information was collected mainly by participation in one or more NFM projects. In our case studies, we can demonstrate that also other channels are important sources of knowledge of more natural solutions, especially training at universities or through institutions for collecting a basic understanding. In their study, Heitz et al. (2009) describe the farmer's self-conception being "experts for soil", getting information from the Farmers' Trade Union, technical papers and agricultural advisors, but in their examined case, farmers often have a weak awareness of muddy flood risks.

3.1.3 Perceived Positive Features of Nature-Based Solutions

Findings from Han and Kuhlicke (2019) suggest that co-benefits are valued positively and important for many stakeholder groups. This result is confirmed by Pagano et al. (2019), particularly if people have direct access to NBS in urban settings and can interact with them frequently. However, the studies assessed by Pagano et al. (2019) focused only on co-benefits related to recreational and aesthetical aspects and other possible positive aspects such as health, wellbeing, cultural values, and economic development have not yet been considered. Interestingly, our respondents did not emphasize the co-benefits for society so much and more emphasis was placed on benefits for nature, economic opportunities and especially on reducing natural hazards.

3.1.4 Concerns About Nature-Based Solutions

Bark et al. (2021) received a mixed response on evidence of the general effectiveness of NBS and at high flows there was also some concern from the stakeholders we interviewed. In the assessment of stakeholders by Bissonnette et al. (2018), more information was needed on the biodiversity and ecological functionality of NBS. Many participants believed that an economic evaluation of services provided by ecosystems is necessary in order to design effective planning interventions.

Several authors for rural settings claim negatively perceived economic aspects as important concerns or barriers to implement NBS, such as Portugal Del Pino et al. (2020). Piacentini and Rossetto (2020) refer to expected high maintenance costs but that stakeholders consider that additional co-benefits might outweigh the high costs. Bissonnette et al. (2018) stated, that many participants believed that an economic evaluation of services such as recreation or aesthetics is necessary to design effective planning interventions. In the case of adapting to sea level rise in Scotland by Liski et al. (2019), rural stakeholders claimed that decision-making should be based on economic rationality and locally derived evidence and that poorly designed schemes might lead to increased maintenance costs. Willingness to manage flood risks with NBS was accepted only if there would be evidence that considerable numbers of residents would benefit from them with increased protection.

TABLE 1 | Interviewed stakeholders (anonymized).

Stakeholder	Stakeholder group according to Zingraff-Hamed et al. (2020b)
Agriculture 1 (business)	Commercial sector
Agriculture 2 (family-owned)	Commercial sector
Research, agronomist	Academia
Water administration (region)	Authorities
Water administration (county)	Authorities
Authority (region)	Authorities
Authority infrastructure 1 (province)	Authorities
Authority infrastructure 2 (province)	Authorities
Nature manager community	Political representatives
Forest administration	Political representatives
Decision maker county	Political representatives
Decision maker community	Political representatives
Representative of interest group for nature and outdoor recreation	Civil society

Pagano et al. (2019) refer to 10% of those interviewed explicitly preferring traditional grey solutions as they are well known and reliable. According to the authors, this stresses again the importance of demonstration pilots and capacity building. The PHUSICOS stakeholders also consider this to be an important aspect and expectation that PHUSICOS as a project could provide such opportunities.

3.1.5 Important Aspects of Nature-Based Solutions From Stakeholder Perspectives

While co-benefits, usability and “neat looking” solutions are very important in urban areas (Hoyle et al., 2017) for gaining acceptance, they might contradict the foundational purposes of NBS such as enhancing biodiversity, and addressing natural hazards, which should be a stronger focus for rural and mountainous areas. Besides validating the durability of NBS, the importance of the economic aspects of NBS that were highlighted in our interviews also agrees with the literature where NBS are implemented in more rural settings. This is also in line with some managerial perspectives from urban areas. Bark et al. (2021) stated that for stakeholders, solutions should be cost-effective and without issues of tenure and coordination of such solutions. Heitz et al. (2009) also highlights economic issues playing a role in mitigation measures for mudflows. Pagano et al. (2019) found that 24% of their respondents perceived the construction and maintenance costs and efforts as limitations to the diffusion of these systems. Santoro et al. (2019) also highlighted that stakeholders expressed the need to have quantitative assessments of the effectiveness of the selected measures in reducing flood risk and expected impacts with specific reference to the costs and benefits of the chosen actions.

3.1.6 Stakeholder Involvement and Participatory Approaches

While Wamsler et al. (2020) critically reflected on stakeholder involvement with limited individual personal interests and a

lack of environmental awareness in urban contexts, in the study by Buchecker et al. (2013), the interviewees experienced the participatory process as an effective means of sustainable decision-making. Only one person who was interviewed doubted that the broad involvement of stakeholders would result in a feasible solution. Others, who had been initially skeptical in this respect, changed their minds during the process.

3.2 Interview Findings

A total of 13 persons agreed to participate in the interviews covering all stakeholder groups from different levels except the two groups media and international organizations (Table 1), which usually are observers rather than intensively involved stakeholders in the co-creation processes (Zingraff-Hamed et al., 2020b).

While the concept of NBS has received a lot of attention among both research and international and European policy in urban areas, the attention received in rural mountain areas is to a lesser extent. Around one third of the interviewees first encountered NBS and their related terminologies with PHUSICOS. The others encountered it with river restoration measures, related to agricultural practices, forestry and one interviewee encountered the NBS concept in an urban context. In the majority of the cases, the information on NBS was received from universities.

Expectations of the Innovation Action funded by the European Commission were related to several aspects (Supplementary Figure S1). Most stakeholders wanted to get new ideas on how to address natural hazards with new solutions and on the project to serve as a starting point to reduce the risks in their area. An important aspect for all stakeholder groups was the desire to find solutions that are attractive and interesting from an economical point of view (e.g., a new business model for farmers and landowners).

“(NBS) offer opportunities that envisage viable alternative measures” (Agriculture 1).

With the pan-European perspective of the project including a retrospective learning case, upscaling and replication of good NBS solutions were perceived to be an attractive opportunity provided by the project. In the words of an interviewee from an authority at the regional level:

“The PHUSICOS Living Labs project generates a positive impact on the territory and on the bodies that manage it in terms of dissemination and information of cutting-edge green engineering techniques” (Authority regional level).

Also, expectations from civil society and NGOs as representatives on the process and the Living Lab approach:

“I think PHUSICOS has great potential for inspiration. (Our institution) wants more people to adopt a mindset and thinking around green solutions. It can contribute to decision-makers adopting more sensible solutions. (...) If PHUSICOS can help lift the focus, something (our

institution) and its members have been lobbying for over many years, this would be a welcome addition” (Representative of interest group for nature and outdoor recreation).

At the beginning of the Living Lab process, NBS were mainly seen as beneficial for nature and providing interesting opportunities for local businesses.

“These solutions are renewable, they have a fairly small carbon footprint and it’s better for boosting the local economy.” (Forest administration political representative).

Only to a lesser extent were other benefits mentioned, such as risk reduction, higher acceptance by the public or multiple benefits. The main concerns were a lack of profitability or a lack of local value added by NBS, the perception of being less reliable and skepticism from many stakeholders towards NBS.

“The costs can be higher; there is a lack of thinking about the maintenance of these solutions which could be very dangerous in the long term. I am quite skeptical about some of these solutions” (Forest administration political representative).

Barriers to implement NBS were seen in a multitude of issues. One set of perceived barriers was the validation of the effectiveness of NBS or applicability at the case site and the time needed for NBS to work (especially related to vegetation). Other barriers were related to human factors such as a lack of knowledge of NBS stakeholder acceptance or a lack of collaboration (**Supplementary Figure S2**). Or, in the words of an interviewee:

“Compared to the grey solutions that have a parameterized dimensioning, the solutions based on nature, in general, suffer from defined dimensioning parameters that allow to determine their goodness and therefore their applicability to extrapolated situations. The human aspects would be especially associated with the lack of companies as well as of available and contrasted know-how to be able to undertake the action successfully.” (Authority infrastructure 2).

When asked for their expectations of Living Labs, most interviewees mentioned the aspects of engaging stakeholders and creating knowledge regarding NBS. Most expressed interests related to economic aspects of NBS; such as

“Combining protection issues with the survival of private businesses which today are the real guardians of the territory” (Agriculture 1).

Other points were raising awareness and stakeholder engagement and the desire to see that NBS is demonstrated to be effective for their region as the main outcome of the Living Lab process.

“By sitting people together, one will achieve a common ground and a common understanding of the problems and challenges. (. . .) A good physical measure that also safeguards the natural values in a sustainable way. Increased understanding among all stakeholders, “make them see the light”!” (Decision Maker County).

Other expected goals to be achieved with Living Labs is to successfully disseminate NBS solutions, raise awareness and provide learning opportunities.

3.3 Comparing and Discussion the Literature Findings and Interviews

Comparing the findings from the literature with the interviews from PHUSICOS (**Table 2**), we can underline a lack of knowledge of ecosystem-based, near-natural or nature-based solutions. This highlights the huge importance of opportunities for learning surrounding NBS and its benefits. This could also take place both in an indirect way, such as visiting implementation sites and discussing implemented projects or in a direct way such as providing documentations, brochures, and newsletters on the topic. In many cases described in the literature, the effectiveness of NBS are perceived very critically and with much skepticism. PHUSICOS stakeholders that were interviewed provided a more positive perspective. Nonetheless, they considered more learning and demonstration of the durability and effectiveness of NBS in particular to be useful.

“Best practice is very important. People are interested in how solutions have been implemented in other places where there is flood risk. If you can show solutions that are working elsewhere, people will take note. There is a lot of learning in good examples.” (Authority Region).

Knowledge institutions such as academia are another key group that can be involved in the learning process.

Academia can play an important part to generate more awareness and positive perception on NBS. They are able to provide a basic understanding of NBS and are widely accepted by most of the other stakeholders as a neutral actor.

Experts might present various challenges, and give examples of green solutions, and then you could discuss these (Decision Maker County).

Stakeholder mapping showed that academia is the major component of both stakeholder groups, “the wise and active stakeholders” and “the observers” (Zingraff-Hamed et al., 2020b). Both groups are mainly in the least affected by the hazard and/or the least affecting the NBS implementation category so they are often not a core actor of the collaborative planning and therefore, in a neutral position.

In addition to demonstrating the durability of NBS, the literature focused on urban areas emphasizes the importance of co-benefits for society. In rural mountainous areas, peculiar

TABLE 2 | Comparison between literature findings and interviews with stakeholders.

Description	Findings from the literature review	PHUSICOS stakeholders' answers
Stakeholder familiarity with NBS and related concepts	Lack of knowledge, but land users and farmers consider themselves the experts [e.g. Heitz et al. (2009)]. Most of the literature underlines the importance of NBS projects for learning and raising awareness/knowledge [e.g. Bustillos Ardaya et al. (2017); Pagliacci et al. (2020)]	About one third have not encountered the concept of NBS before the start of PHUSICOS, "entry-point" knowledge often provided from universities and related contacts
NBS benefits perceived by stakeholders	Mainly urban NBS in the literature, mainly co-benefits for society are valued Han and Kuhlicke (2019), managerial views relate to easier maintenance Bark et al. (2021)	Interviewees mainly refer to benefits for nature and express potential economic opportunities
Concerns of stakeholders on NBS	NBS are less effective especially in severe events Pagano et al. (2019), high maintenance costs Portugal Del Pino et al. (2020), little acceptance for solutions that are not aesthetically pleasing Hoyle et al. (2017)	Evidence of durability or functionality is largely missing, effectiveness is lower, maintenance is more costly, fear of invasive species
Perceived barriers to NBS by stakeholders	Often, a lack of knowledge and awareness of evolution and importance of participation [e.g. Venkataraman et al. (2020); Buchecker et al. (2013)]	Lack of knowledge, PHUSICOS project approach could help to overcome or address this issue
Collaborative processes	Mixed experiences, critical reflections [e.g. Wamsler et al. (2020)] as well as positive reports Buchecker et al. (2013)	Expectations relate to raising awareness, learning, experiencing hands-on cases, collecting experiences, demonstrating effectiveness and viability, and new attractive business models

technical, environmental and socio-economic features can be detected (Baills et al., 2021; Strout et al., 2021), and these environments deal more often with natural hazards such as flooding, landslides, rockfalls or snow avalanches (Evans and Clague, 1994; Haritashya et al., 2006). Implemented NBS in the catchment areas can provide benefits and risk reduction for the entire watershed including heavily populated urban areas (Albrecht et al., 2017).

highlighted importance of the economic aspects of NBS in our interviews with the stakeholders can be found both in literature where NBS are implemented in more rural settings and in literature presenting managerial perspectives of NBS in urban areas. Economic aspects and financing of NBS are identified as one of the major challenges to mainstream NBS. A number EU research- and innovation-funded projects currently strive to increase the knowledge on funding and business models for NBS (Mayor et al., 2021). A key challenge is that benefits provided or created by nature and NBS are largely public goods and services that either have no markets or market prices or have costs that are relevant only in the distant future (Schweppe-Kraft and Grunewald, 2015).

Several attempts have been undertaken to describe the value of nature, both in monetary and non-monetary terms also as a basis for the development of business models. Calculating economic values is already considered challenging. Only a few studies on the monetary value of NBS in comparison with grey solutions exist (Debele et al., 2019). This is due to the fact that the monetary value of the social co-benefits is difficult to assess and it is even more difficult to adequately consider them in collaborative processes (Perosa et al., 2021).

The difficulty of monetizing especially socio-ecological benefits raises additional challenges for private businesses such as farmers. Neither are they included in market prices, nor are they are deeply rooted in relevant mechanisms such as the EU Common Agricultural Policy with funding regimes and subsidies heavily influencing the business models of farmers—despite the efforts taken for integrating strong greening and environmental requests (e.g. Lupp et al., 2014 and Lupp et al., 2015 for the case of biomass

production for energy purposes). Thus, private stakeholders are hesitant in engaging or investing financially in NBS, and most business models currently depend on direct or indirect interventions to mitigate the lack of market mechanisms through policy instruments and incentives valuing the benefits generated by NBS (Mayor et al., 2021).

Nonetheless, the power of economic instruments has been demonstrated by the results of The Economics of Ecosystems and Biodiversity (TEEB) study (Kumar, 2011), and some of the created co-benefits can be conveyed in economic value. Examples of this include increased real estate value next to urban green or restored river sections in urban areas (Luttik, 2000; Gerwien, 2020) or payment schemes for ecosystem services such as the financial support of the Munich Public Works for organic farming in the Mangfall Valley. This included marketing activities of dairy products originating from the area in order to avoid excessive, expensive technical purification for their main source of drinking water for the city (Grolleau and McCann, 2012).

Efforts therefore strive to demonstrate for stakeholders the cost-benefit within broader assessment approaches. These approaches aim to describe the benefits of NBS by accounting both monetary and non-monetary values through combining multidisciplinary approaches and integrating physical, environmental, social, human and economic features (Dumitru and Wendling, 2021). Multi-criteria tools comprising a set of indicators based on the application of multi-criteria decision analyses including stakeholders in both the weighting and assessment procedures can help to compare the effectiveness of different nature-based, hybrid and grey design solutions (Pugliese et al., 2020).

Finally, despite several attempts to explain stakeholder perception and awareness, explanation models do not elucidate why stakeholders take action or not (Lindell and Perry, 2012). Appraisal of risks and knowledge does not necessarily result in protective action and may even cause dissonant attitudes. Even with much awareness on NBS, the motivation to take action is often low, or grey engineering solutions are preferred. Key motivational factors

to generate action can be sharing of the responsibility of implementing a solution among different stakeholders, the collective engagement in prevention, and the importance of dialogue (Maidl et al., 2019).

4 CONCLUDING REMARKS AND OUTLOOK

With the findings from the literature review and with the first interview round of selected PHUSICOS stakeholders, a number of challenges need to be addressed to overcome the lack of a broader implementation and mainstreaming of NBS.

Despite their importance on political and research agendas, the knowledge of on-the-ground stakeholders on NBS is limited. Sometimes, there is even a lack of awareness about the natural hazards and exposure to the risks. In many cases described in the literature, the effectiveness of NBS is perceived very critically and much skepticism exists towards such solutions. While the PHUSICOS stakeholders that were interviewed provided a more positive perspective towards NBS, still for this group, learning opportunities, site visits and “hands-on cases” to demonstrate the durability and effectiveness of NBS was seen as particularly useful. Knowledge institutions such as academia can be an important group to contribute to such a learning process and play an important role as trustworthy, neutral actors in the NBS negotiation processes. Applying concepts such as Living Labs with its philosophy of all stakeholders contributing by meeting on equal ground can create an atmosphere of trust and understanding to support finding and implementing NBS solutions.

While for public landowners or real estate developers in urban areas, the creation of multiple co-benefits might already be a critical driver for successfully implementing NBS, the situation in rural mountain areas can be more complex. Landowners providing the space for NBS solutions and in particular farmers often initially perceive NBS as a limitation to their economic potentials for gaining revenues from their productive land. It is therefore vital for this group to demonstrate with real-life examples that NBS can be an interesting opportunity also in economic terms. Co-benefits of NBS therefore need to be measured and valued in a clear, widely accepted manner with sound methods, tools and indicators. Assessment frameworks can describe value arising for the different stakeholders and can lay the foundation for business models related to the implementation, managing, monitoring of NBS or resulting new opportunities from such measures.

With many expectations expressed at the beginning by the interviewed stakeholders in the PHUSICOS project, it will be interesting to follow up with the stakeholders through the Living Lab processes and the evolution of their perceptions on NBS. Learning, building trust and intensive in-depth collaboration processes might be the key elements for triggering action in real life, mainstreaming NBS and

gaining equal or more acceptance of NBS over traditional grey solutions.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

In line with the Research Ethics Procedures of the Technical University of Munich and project partner institutions based on the mentioned EU, EEA and respective country regulations, the participants received written information on how the data would be used and were asked to give their consent to participate in the interviews according to these guidelines. We obtained consent from all research participants prior to the interviews and handled their confidentiality and interview data according to this consent.

AUTHOR CONTRIBUTIONS

Conceptualization: GL, AZ-H; research design, methodology: GL, AZ-H, JH; validation, SP; AO and AS; literature review: GL and JH; investigation at sites, conducting interviews, transcripts, translation: NS, AM, TW-K, MO, TF, EM-B, and IA; writing: GL, JH, and AZ-H; project administration: AS, AO, BK, and ML; funding acquisition, AO; BK, supervision, AO, AS, SP, and ML.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2021.678446/full#supplementary-material>

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