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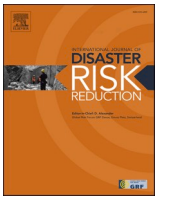

Where does local and indigenous knowledge in disaster risk reduction go from here? A systematic literature review

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ABSTRACT

The embeddedness of local and indigenous communities in their environments has led them to develop time-tested knowledge and practices to prepare for, mitigate, respond to, and recover from the impacts of natural hazards. Collectively, these are referred to as local and indigenous knowledge (LIK) and have gained a niche in disaster risk reduction (DRR) scholarship. We conducted a systematic literature review, identifying 325 articles that were qualitatively coded to identify what practices constitute LIK, patterns in how it has been studied, and how current understanding of LIK fits to the Sendai Framework. We found a plethora of strategies that communities mobilise, from hazard forecasts to livelihood-based adaptation, with the study of these concentrated in middle- and high-income countries. Efforts to integrate knowledge (LIK and scientific) and power spheres (top-down and bottom-up) are increasingly prominent themes in disaster scholarship. There is a recognition of LIK in the Sendai Framework priority areas, although still embryonic, which we link to the existing body of knowledge in literature. Our synthesis pieces together a holistic understanding of LIK to offer a more concrete appreciation of what LIK is and how it can be further relevant for DRR efforts.

1. Introduction

The World Meteorological Organisation [1] reports a five-fold increase in the number of disasters in the past fifty years. Meanwhile, the International Federation of Red Cross and Red Crescent Societies [2] states there was a 35% surge of disasters since 1990s alongside an increase in their intensities. This trend has seen an accompanying rise in scholarship in disaster studies [3]. In most instances, the scholarship has been shrouded by contested and conflicting ideologies on which knowledge system best fits for risk reduction. Consequently, a growing number of scholars have since advanced the idea that local communities' embeddedness in their environments has led them to develop time-tested knowledge, coping practices, and adaptation strategies to prepare for, mitigate, respond to, and recover from the impacts of disasters [4–9]. The strategies and practices developed and used by communities to reduce disaster risks form the basis of cultural adaptation [10], giving rise to what scholars call as "culture of disaster" [11,12] or "disaster subculture" [13,14]. Communities gain and develop these strategies and practices as they are considered the "zero-order responders" in dealing with the frequent disruptions of hazards affecting them [15]. In the existing literature on disaster risk reduction (DRR), such strategies and practices emerge as products of what is conjunctively referred to as local and indigenous knowledge (LIK).

When taken independently, the term "local knowledge" is derived from a community's place-based relationship with the local environment while "indigenous knowledge" is gained from long-term cultural ties or traditional ownership of a place [16,17].

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Similarly, the Intergovernmental Panel on Climate Change [18] characterises the former to be the understandings and skills specific to where people live, while the latter is developed out of longstanding interaction with the natural environment. Distinctions between the two exist in literature. However, in reality, blurred lines emerge in demarcating what is local or indigenous since communities often use varied sources of knowledge concurrently [19,20].

The importance of LIK in the general developmental sense has been emphasised as early as the 1970s [10]. In the aftermath of the 2004 Indian Ocean earthquake and tsunami, the relevance of LIK to DRR was put into the limelight when the coping strategies of indigenous communities were widely publicised [21]. The oral story of the Simeulue people reminded how inherited knowledge can serve as an early warning system to save lives [22,23]. Literature on LIK has since gained a niche in disaster scholarship with broader implications on the field. A myriad of different terms has emerged from the way scholars have attributed harnessing local capacities such as "community-based", "participatory", "multi-stakeholder", "grassroots-level", "people-centred", among others. In the Sendai Framework for Disaster Risk Reduction, the current global framework guiding efforts to reduce disaster risk, LIK is acknowledged as an essential complement to scientific knowledge in the assessment of disaster risks and the development and implementation of policies and programmes [24].

The existing scholarship on LIK in disaster studies is extensive. However, the DRR body of knowledge on LIK is primarily constructed from case studies. To date, there has been limited effort to synthesise what we understand about LIK more collectively. There have been some studies that have reviewed LIK in specific DRR contexts. These include the adaptation of indigenous Taiwanese communities to climate shocks [25], the integration of indigenous and scientific knowledge for flood risk reduction [26], the development of local knowledge for disaster preparedness [27], the inclusion of communities in early warning systems [28,29], and the state of integrated, multi-scale disaster research [30]. These reviews deal with LIK in specific parameters, but a more holistic synthesis of LIK in DRR in the broadest sense – unrestrictive of affinity to a country, hazard, disaster phase, or timeline – is missing. How then does LIK stand more holistically especially within the disaster discourse that is still being polarised by the dichotomy of what knowledge system best fits for DRR? This systematic review is conceptualised as a "reflective pause" to assess the landscape and current state of LIK in DRR literature.

While a systematic literature review can serve a critical role in providing synthesis to identify research priorities and gaps [31], we further posit that such synthesis gains relevance if analysed against a backdrop of policy frameworks. Hence, by reviewing LIK in DRR, we endeavour not just to provide the current state of knowledge but also to give guidance to both scholars and policymakers to progress the Sendai Framework, of which the use of LIK is part of its advocacy [24]. We draw on three research questions (RQs) as the bases for this review:

(RQ1) What forms of LIK appear in disaster literature?

(RQ2) How has the research focus of LIK in disaster scholarship evolved over time?

(RQ3) What are the priorities of the Sendai Framework (not) being captured in the current understanding of LIK in the DRR body of knowledge?

In the following sections, we first provide a theoretical orientation of LIK in DRR. We then present our methods, including the review search strategy, document selection and screening, and coding process and thematic analysis. Our findings are presented in three sub-sections aligned with the research questions that focus on the identification and classification of LIK in the current body of knowledge, research themes on how LIK has been studied over time, and how these themes fit to the Sendai Framework. Finally, we discuss implications for future research and emerging gaps.

2. Theoretical orientation

LIK has sometimes been interchangeably referred to as "traditional ecological knowledge," "indigenous technical knowledge," and "endogenous knowledge" [21] apart from other associated terms such as "ethnic," "folk", and "vernacular". The breadth of literature on this topic has resulted in diverging characterisations among scholars. While, on the one hand, the divergence may imply a comprehensive understanding, on the other, it signals continued contestation. For example, Matti & Oǧmundardóttir [32] use "local knowledge" over "indigenous" or "traditional" since the former is restrictive to non-indigenous local knowledge, while the latter has static connotations implying that such form of knowledge is not evolving. Meanwhile, Mercer et al. [33] assemble several literatures to define indigenous knowledge as "a body of knowledge existing within or acquired by local people over a period of time through the accumulation of experiences, society-nature relationships, community practices and institutions, and by passing it down through generations" (p. 217). Similarly, Cuaton & Su [7] aggregated local and indigenous knowledge as "a body of different types of knowledge and practices of societies accumulated through a continuous interaction with their natural surroundings" (p. 2). The characterisation that is gaining wider acceptance from scholars is perhaps best stated by UNESCO [34] which defines LIK as "the understandings, skills, and philosophies developed by societies with long histories of interaction with their natural surroundings".

The burgeoning permutations of how LIK is characterised in disaster studies merit a simple but encompassing definition to be inclusively representative of the different ideas and connotations across the breadth of literature. Therefore, insofar as this study is concerned, LIK is collectively referred to as the developed understandings (perceptions, beliefs, philosophies) and self-help measures (inherent skills, local ways of doing things, traditional practices) used by communities to prepare for, mitigate, respond to, and recover from the impacts of natural hazards. This definition is in line with Dekens' [27] people-centred characterisation that focuses on "what the residents know about natural hazard risks and what they believe and do about them in a given situation" (p. 5). By borrowing the term "self-help measures" from Plate [35], it is implied herein that knowledge manifests when communities use their efforts and

resources on the ground with little to no reliance from others. Such knowledge can be developed over many generations and handed down, dynamic due to the influences within and outside a community [27], or used concurrently with other complementary forms of knowledge in the community [19,20] ascribing to a trend called "cognitive polyphasia" [36]. While Agrawal [16], Gaillard [37], and Griffin & Barney [19] caution adhering to a LIK and scientific knowledge dichotomy, we distinguish the two for clarity and operationalisation. LIK is acquired experientially, grounded in the sociocultural context of the need to address issues of everyday living [26]. It arises from context-specific and outcomes-based understanding of the natural realities [38]. On the other hand, scientific knowledge is developed through a formal evidence-based technical systematisation of information to carefully provide explanations of phenomena [39]. We further operationalise "community" to mean being a part of any urban, rural, culturally and socially distinct (e.g., indigenous, tribal, ethnic), homogenous, or heterogeneous groups where LIK emanates. Such characterisation broadly encompasses the diverse contexts and complexities of how community can be defined in the developmental and DRR-related work [40]. Regardless of community structures, residents do have the understandings and self-help measures at their disposal in the face of hazards.

Across past and current global DRR frameworks, the recognition of LIK which forms part of community capacity for risk reduction has mostly been juxtaposed with scientific knowledge. In the Yokohama Strategy and Plan for Action in 1994, traditional methods of reducing disaster impacts were recognised to be "supplemented" and "reinforced" with scientific knowledge [41]. In the Hyogo Framework for Action in 2005, incorporation of LIK was supported to provide understandable risk information, albeit alongside more generous emphasis to strengthen scientific and technical DRR capacity [42]. Such adjunct representations of LIK have been carried over in the Sendai Framework, where LIK is presented to "complement" scientific knowledge in risk assessments and policy developments [24]. Across the development of these three global frameworks, Tozier de la Poterie & Baudoin [43] draw attention to how communities went from being regarded as valued partners to aid recipients alongside a significant shift to support technological solutions for DRR.

The need to holistically review the literature on LIK stems from the phenomenon that a science-based stance still dominates the disaster discourse. Reasons include the persistent technocratic bias in disaster management and the dominant influence of scientific thinking in scholarship which favours more technical and formal means towards DRR. Generally, a paradox exists because LIK remains underutilised in the actual practice of DRR, yet it is widely praised in academic literature and policy environment [44]. One potential barrier for its underutilisation could be that we have fragmented thinking of LIK, which is reflected by the contested and inconsistent terminologies that surface in literature. But the fragmentation goes beyond naming conventions, as ideally, there should be a unified understanding of what constitutes the characteristics of LIK, but still none exists despite the breadth of literature. With the sustained academic and policy attention of LIK in DRR, how can we translate diverging understandings to an integrated and more collective view of what we know about LIK from past studies? We conducted this systematic review to piece together knowledge about LIK to establish a more holistic perspective to assist scholars, practitioners, and policymakers appreciate what LIK is and how it can be (further) relevant for DRR efforts.

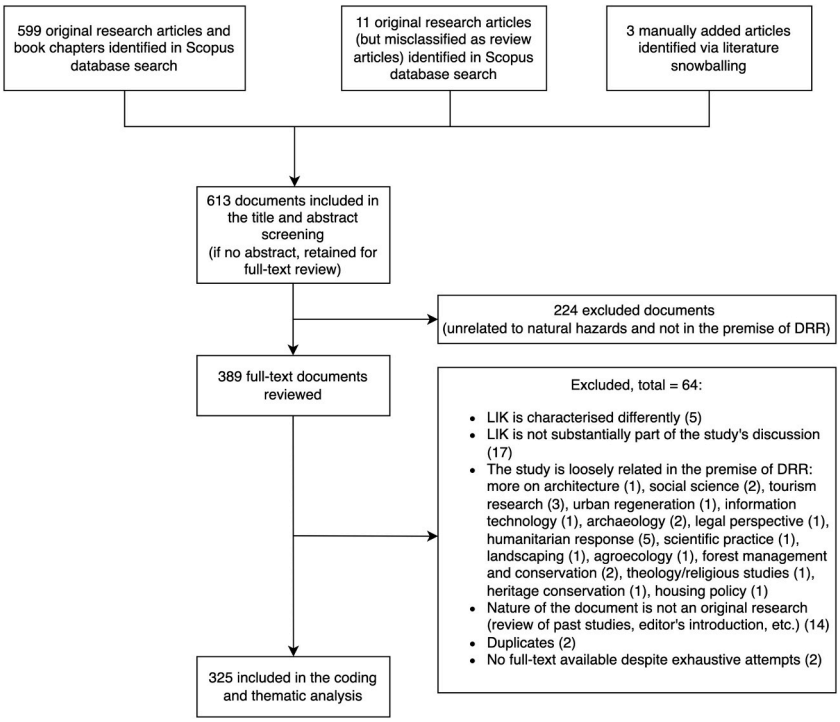

Fig. 1. Document selection and exclusion PRISMA diagram.

3. Methods

This study aimed to identify what forms of LIK appear in DRR literature (RQ1), themes in the longitudinal evolution of LIK (RQ2), and to what extent current and past foci fit to the Sendai Framework (RQ3). The following sub-sections present the search strategy, document selection and screening, and the coding process and thematic analysis. We followed recommended best practices for systematic literature reviews [45,46] to enhance the rigour in synthesising the extensive body of knowledge on LIK. A visual summary of the document selection and screening process is presented in Fig. 1 following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram. PRISMA is a reporting guideline for systematic reviews instigating transparency in the identification, selection, appraisal, and synthesis of studies [31].

3.1. Search strategy

Our search was bounded to the Scopus database to identify documents included in the systematic literature review. Scopus is one of the largest abstract and citation databases for peer-reviewed literature. As a point of comparison, it indexes 66% more unique journals than Web of Science [47]. Additionally, Scopus is preferred since it has extensive quality assurance processes in indexing data elements monitored by an independent Content Selection and Advisory Board [48]. An initial keyword search was conducted to determine the coverage and relevance when using the combination of the following principal words: "local," "indigenous," "knowledge," and "disaster". The resulting items were then used to inform the final advanced document search. On top of the initial keywords used, additional search operators were utilised, including Boolean ("OR", "AND"), proximity ("W/*n*"), and wildcard ("*"). The final combination of words and operators ("search string") was as follows:

TITLE-ABS-KEY ((local* OR indigenous OR traditional W/5 knowledge) AND disaster*)

The search string implies that any of the words "local" (including any other variations such as "locals'," "locally-known," etc. as denoted by the asterisk), "indigenous," or "traditional" should be within a distance of five words from "knowledge". The word "traditional" was included as this was found to be used synonymously in many articles in the initial search. The proximity operator of a distance of five words reasonably narrowed the search's intended focus. It was also a conservative and inclusive assumption that allowed to capture phrases such as "…locals' or the community's knowledge…". Additionally, "disaster" was used to confine the focus of LIK to disasters. If the word combinations matched with any of the texts from a document's title, abstract, or keywords ("TITLE-ABS-KEY"), then such document was included.

The search string yielded 599 document results on 5 August 2021 inclusive of original research articles and book chapters in the English language. Conference papers and review articles were excluded since the former often represent works in progress for most fields of relevance, while review articles would have created redundancy in the reporting of themes. An additional eleven (11) documents were included in the pool of items screened, which Scopus misclassified as review articles. We also manually added three (3) articles of relevance [13,22,49] identified via literature snowballing. Also known as backward search, this technique includes relevant works cited in the articles being reviewed but were not captured by the search string. Overall, 613 documents were included in the title and abstract screening.

3.2. Document selection and screening

To be included in the next round of review (full-text review), the following criteria were used to filter the documents: (i) the context of "disaster" must have been related to natural hazards (e.g., meteorological, geophysical) or environmental threats such as climate change (e.g., sea-level rise, drought); and, (ii) LIK should have been in the premise of DRR (mitigation, preparedness, response, and recovery and rehabilitation). As such, studies dealing with disasters in the context of biological hazards (disease outbreaks), chemical (oil spill, contaminations), technological (nuclear), societal (civil unrest, armed conflicts, fire due to arson), or those that explored LIK in the context of traditional medicine, forest management, and other topics not explicitly related to disasters were excluded. By default, if a document did not have an abstract, it was automatically carried over for full-text review. A total of 389 documents qualified and were included in the full-text review, of which 13 items did not have abstracts.

Each document was thoroughly reviewed before coding for themes. A total of 64 documents were removed at this stage for the following reasons: (i) LIK was characterised differently, e.g., local expertise of formal disaster actors rather than that of communities' ($n = 5$); (ii) LIK was not substantially part of the study's discussion ($n = 17$); (iii) the general premise of the study was loosely related to DRR ($n = 24$); (iv) the nature of the document was not original research but more closely a review of past studies ($n = 14$); (v) duplicate articles ($n = 2$); and, (vi) no full text available despite exhaustive attempts ($n = 2$). The remaining 325 documents were systematically coded using thematic analysis.

3.3. Coding process and thematic analysis

Coding is the derivation of a summative thought from words, phrases, or sentences ("codes") which represent the meaning of a portion of a data [50]. In this study, the process was facilitated using NVivo 12 software, and preference was given to ideas developed in the findings, discussion, and conclusions that form part of the core arguments of the documents. Prior to coding, the documents reviewed were classified either as fieldwork- or non-fieldwork-based studies. We considered a study to be fieldwork-based if it deliberately articulated any form of interaction with communities in gathering data, therefore we made it the basis for eliciting LIK as practised on the ground (see RQ1). Otherwise, documents were classified as non-fieldwork if there was no interaction with communities in the primary data collection (e.g., comments, desk research, and theoretical frameworks). Thematic analysis was then employed across all the codes (regardless if from fieldwork- or non-fieldwork-based studies) to identify the patterns of meaning –

herein more formally referred to as *themes*.

Thematic analysis groups the derived codes to represent bigger picture ideas. We followed the six-step process for theme identification pioneered by Braun & Clarke [51] which can be summarised to include data familiarisation, data coding, and theme development and revision. While often used in qualitative research, there have been doubts about how scholars have adopted thematic analysis rigorously and methodically in their research methods [52,53]. In this light, we have also considered the protocols suggested by Nowell et al. [53] and Castleberry & Nolen [52].Some of these protocols include aligning the data collection methods with the research questions, as well as peer debriefing to crosscheck the analysis with a co-researcher who knows a substantive area of the inquiry.

A hybrid of deductive and inductive approaches was used to identify themes. The former develops themes under existing or preconceived concepts and ideas, while the latter is directed by the content of the data to generate common themes [51]. The inductive approach was applicable in answering RQ1 and RQ2 since one of the objectives was to understand emergent themes that have surfaced in literature. On the other hand, the deductive approach was applicable in answering RQ3 since we wanted to analyse how the identified themes in literature fit within the four priority areas of the Sendai Framework. During the theme development, multiple themes could be extracted from a single document. Hence, there is no implied congruence regarding the frequency of themes to the number of documents reviewed.

4. Findings and discussions

To advance the recognition of LIK in DRR, we first present a synthesis of how scholarship has, to date, characterised LIK in fieldwork-based studies. We found seven forms attributed to how LIK is used in DRR, from hazard forecasts to livelihood-based adaptation (RQ1) (see Section 4.1). We then present the six identified themes derived from all the documents reviewed from both fieldwork- and non-fieldwork-based studies (see Section 4.2). Emergent themes such as exploring the nexus of LIK and scientific knowledge link to the research foci of how this research agenda has been studied in scholarship (RQ2). Lastly, these themes are then analysed to the Sendai Framework to understand what priority areas are (not) captured in the current understanding of LIK in the DRR body of knowledge (RQ 3) (see Section 4.3).

4.1. LIK on the ground: Encounters from fieldwork-based studies

Communities mobilise a plethora of LIK which highlights their ingenuity to come up with self-help measures to protect themselves and their assets in the face of hazards. While the literature gains an appreciation of natural hazards and their impacts and often highlights LIK in a positive light, we also found that in some instances, this knowledge emerges to counteract the absence of institutional support. However, the greater picture remains obscure since, based on the documents reviewed, low-income countries receive a meagre 5% share of fieldwork-based studies compared to middle- and high-income countries which receive 73.5% and 21.5%, respectively (see Fig. 2). The same trend also exists with non-fieldwork-based studies: 1.6% in low-income countries, 50.8% in middle-income countries, and 47.5% in high-income countries (see Fig. 3). This geographical skewness can mirror the publishing bias in academia to disproportionately give less attention to data-scarce communities. One potential reason of this skewness may also be that some countries (or group of countries) receive more attention due to their higher hazard exposure. Clearly, however, there remain challenges in the practice and policy environments of DRR to gain balanced and more diversified representations about grassroot

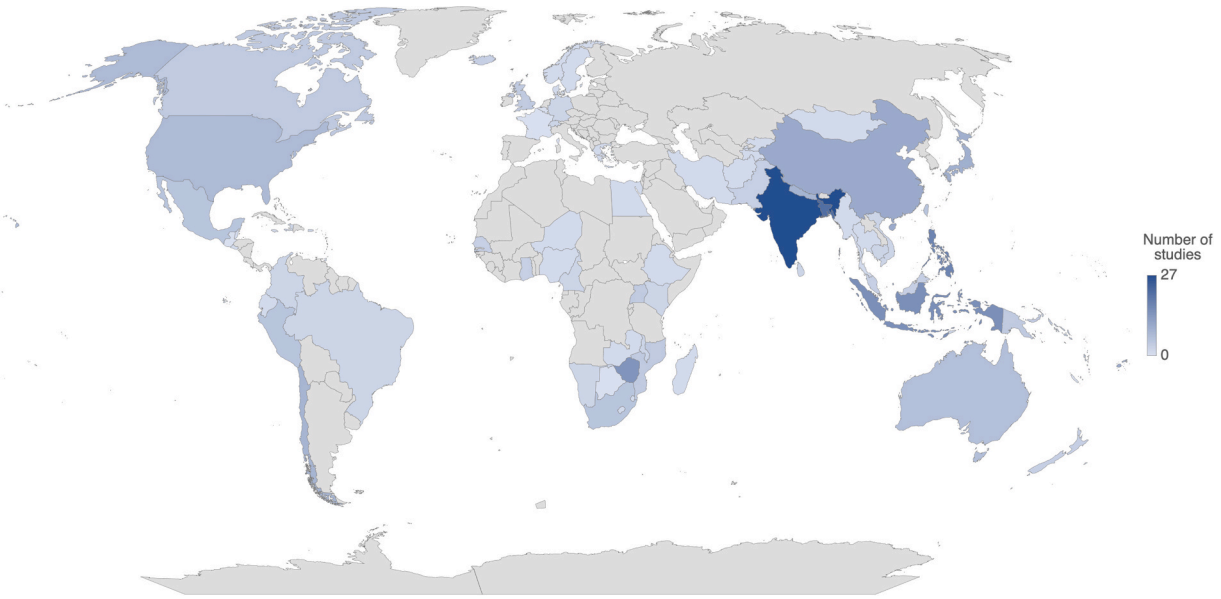

Fig. 2. Geographical distribution of fieldwork-based studies. (Note: Some studies are conducted in more than one fieldwork location.)

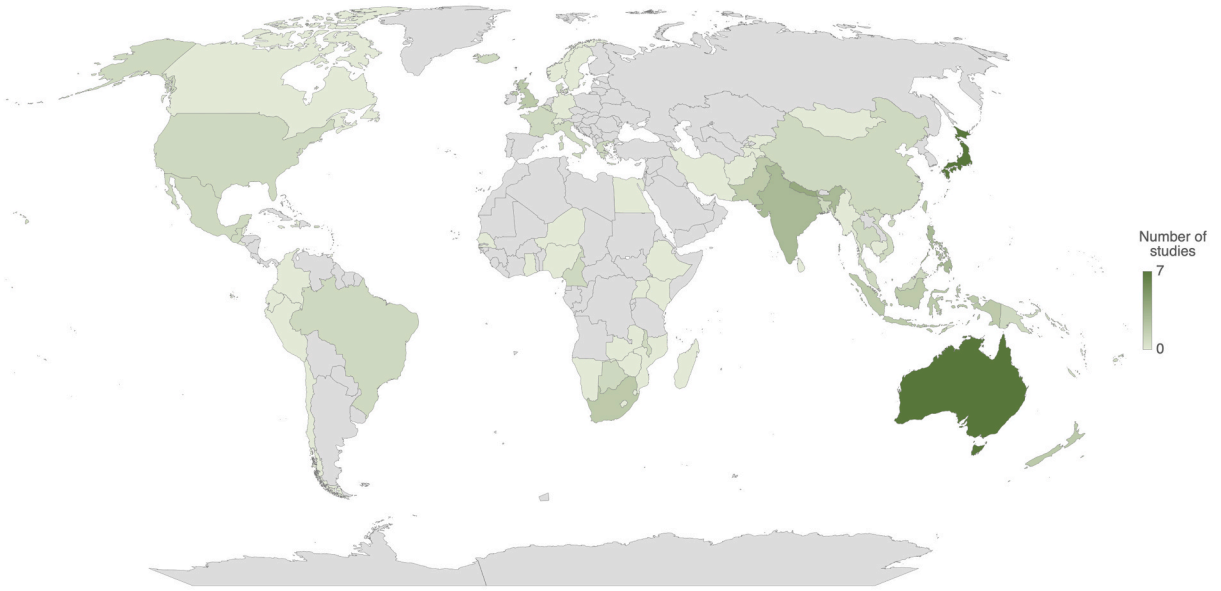

Fig. 3. Geographical distribution of non-fieldwork-based studies. (Note: Country associations with non-fieldwork studies are based on the location a study focuses (e.g., a study discussing the state of LIK in Australia is counted for Australia). Some studies are associated with more than one location, while others do not represent specific locations.).

capacities of low-income countries to manage risk reduction efforts.

In the following sub-sections, we discuss characteristics of LIK extracted from fieldwork-based studies. Early warning systems and risk knowledge and perception influence the precautionary and adaptation strategies that communities use in response to hazards, and these are shaped by belief systems and community dynamics, such as social cohesion (see Fig. 4). We move away from presenting the use of LIK in the typical disaster cycle paradigm as we acknowledge that these practices do not occur very linear or cyclical (see [54]), but instead, there are overlaps and overarching instances when these are used when disasters unfold. Hence, we are not limiting *when* LIK occurs against a predefined disaster phase as there is a continuum of ways communities use their knowledge and practices for disaster response.

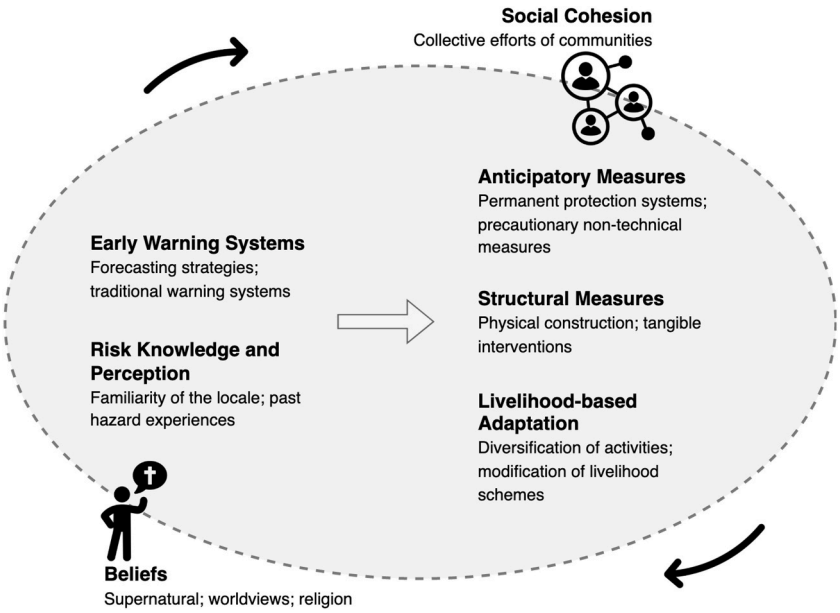

Fig. 4. The interconnectedness of the different forms of LIK as derived from the synthesis of fieldwork-based studies.

4.1.1. Early warning systems

Early warning systems which include, but are not limited to, alarms, news, and warning signs, provide information for populations exposed to hazards for them to be receptive, be prepared, and consequently take action [55]. It is the continuous interactions between communities and their surroundings that enable them to identify signs and signals from nature that can indicate impending hazards. Some scholars, however, note that these environmental cues are becoming less reliable due to climate variability [4,9,56–58] and environmental degradation [9,59]. Regardless, communities still hold and use these practices, and they will continue to do so as long as these practices aid in reducing risk.

Forecasting, the first stage in more general warning processes [35], is common among local and indigenous communities. Flooding forecasts in Cambodia [58] and Malawi [9], for example, are based on the direct observation of clarity, speed, and sound of water. In Sri Lanka, predicting landslides is based on the assessment of unusual earth cracks and understanding the impact of heavy rainfall on the water table [8]. Meanwhile, drought forecasts in Lesotho and Eswatini are based on the changing rainfall patterns and strong winds blowing in particular directions [60]. A myriad of examples exists in literature regarding the flora- and fauna-based forecasting strategies that depend on the phenology of plants and the behaviour of animals to foretell both general weather conditions and occurrence of hazards. Some examples include: whales swimming in particular directions to signal approaching storms in India [61]; an abundance of sea urchins and starfish along shorelines to foreshadow impending typhoons in the Philippines [62]; and, night-flowering jasmine to predict the onset of heavy rainfall in India [63]. To relay forecasts, some communities also use local technologies to disseminate information or trigger alarms, such as using bamboo slit drums and mosque loudspeakers in Indonesia [64] and community drums and indigenous loudspeakers in Afghanistan [65].

Apart from the wealth of examples on forecasting strategies that we found in literature, we also saw an uptick in attention highlighting how communities informally integrate traditional forecasts with more technical sources of hazard information such as from televised meteorological forecasts. For example, Balay-As et al. [4] noticed how radio forecasts serve as confirmation when traditional signs of dark-coloured sky hint an approaching rain as observed from an indigenous group in the northern Philippines. The hybridisation of different knowledge sources (see Section 4.2.2) happens then as more communities – especially from low- and middle-income communities with heavy reliance on LIK – begin to gain access to technologies. This hybridisation can be positive, helping communities better prepare for disasters by integrating sources of hazard information. Inversely, however, such integration of knowledge systems often still sees a dominant narrative in favour of scientific knowledge. This implicit overshadowing can lead to the eventual disregard of LIK resulting to the overreliance to the technicalities of scientific knowledge.

4.1.2. Risk knowledge and perception

The awareness and judgement of communities to environmental threats are baseline conditions for disaster preparedness. Risk knowledge and perception are developed when communities are embedded in or hold understanding about their environment, as day-to-day encounters teach them what these hazards can bring, why and how they occur, and how to cope with them. We identified two ways how risk knowledge and perception are gained. The first is through familiarity of the locale, while the second mechanism is through accumulation of past hazard experiences.

One's familiarity with a place provides insights into local conditions and environmental elements, such as in Nepal where villagers are aware that landslides affecting their farmlands occur due to weak geology exacerbated by water table conditions and impact of heavy rainfall [66]. In the typhoon-prone Philippines, the structure of storms is well understood by some communities and they can explain the concept of storm surges without scientific translation [67]. Similarly, in Australia, communities have developed a more intimate understanding of cyclones and these are recalled as sensory experiences with specific elements and characteristics [68]. In a community bushfire mapping activity, also in Australia, communities' spatial awareness of their environment enabled them to identify areas of increased risk, such as dense bushland as well as routes for safe evacuation [69]. Communities residing around the base of active volcanoes in Indonesia have developed localised terminologies to the hazardous elements brought by phreatic eruptions and this is one of the ways to understand their vulnerabilities [70]. These examples highlight that familiarity of place transcends beyond spatial knowing but also entails an understanding of the elements and conditions that affect a place. In most instances, this understanding of place results in localised views which lead to the development of context-dependent knowledge systems helpful for communities to prepare for disasters.

Past hazard experiences are also sources of risk knowledge and perception among communities. Lessons are absorbed from past events and are applied. The 1977 flood in Mozambique, for example, served as the maximum benchmark providing a flood line defining acceptable risk for communities [71] while in the Philippines, the impacts or severity of past flood events are remembered through anthropometric measurements such as knee, waist, and hip depths [72]. Households' experiences with landslides in Peru were vital in understanding the hazard's occurrence and reactivations (dates, magnitudes, and damages) which were used for hazard mapping [73]. There are also increasing efforts to preserve these past experiences and ensure transfer between generations, such as in Japan. In some museums, disaster encounters are conveyed as stories to pass local knowledge for future DRR in line with the *kataribe* tradition of sharing lessons and experiences [74]. Generally, while such past hazard experiences provide historically grounded accounts on what to expect or what can possibly happen, extreme events can sometimes overthrow the relevance of these experiences [75–78]. Such has been demonstrated, for example, during the 2000 floods in Mozambique [71]. The maximum flood level benchmark left by the 1977 flood has been surpassed, leaving communities uncertain of the thresholds of what could now be risky or safe as they anticipate related hydrological events.

4.1.3. Anticipatory measures: Mitigation and preparedness

To reduce risk in the face of hazards, communities take early actions which can either be through permanent protection systems

and strategies ("mitigation") or precautionary non-technical measures ("preparedness") [35]. Due to their forecasting strategies and prior knowledge of local hazards, communities become receptive and develop safety-seeking anticipatory measures. In Sri Lanka, mitigation measures undertaken for landslides include planting and reserving tree belts near houses, terrace cultivation, and adoption of a land utilisation pattern where the upper areas are retained as forest reserves, the middle portions as housing areas, and the lowest portions as paddy fields [8]. Similarly, in India, land use strategies are in place to prepare for landslides such as: avoiding flood- or landslide-prone locations when building a house; converting hillsides into level terraces (including managing water flows between terraces); stabilising slopes with trees; and managing slow rainwater runoff by creating a network of ponds [79]. To mitigate the impacts of flooding, certain housing adjustments are undertaken by many communities across countries (see Section 4.1.4).

In terms of preparedness measures, communities in the Philippines adopt strategies for impending typhoons and typhoon-induced flooding: securing roofs with ropes and cutting down tall and decaying trees [67]; reinforcing wooden or thatched houses by tying with wires, nailing down walls and windows, and putting heavy items (sandbags, tyres) on top to protect roofing [72]; and practising a tradition which involves replacing old thatched roofs with newer ones to make sure that these can withstand heavy rains and winds [4]. Food preservation is also a common preparedness strategy to ensure food security in times of disaster. Examples include traditional fermentation of terrestrial and marine food in Tuvalu [80] and keeping food within pots and burying them underground as practised in Bangladesh [81]. All these anticipatory measures attest to the general notion in disaster discourse that communities are indeed not helpless as they can proactively prepare for forthcoming hazards. Hence, communities should not be merely regarded as passive victims and recipients of external aid but active agents for DRR measures [15,72,82].

4.1.4. Structural measures

According to UNDRR [83], "Structural measures are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems". The most common structural interventions captured from the documents reviewed were those that are adopted by communities in response to flooding. These include raising houses either on piles, stilts, platforms, or plinths [6,79,84,85], on higher grounds [9,86], or elevating room levels through earth-filling [72]. Additionally, still in response to flooding, sandbags are used [87,88], retaining walls around farmlands are constructed [6], and walls and foundations of houses are strengthened using local materials [9].

Other structural measures are embodied in the different seismic-resistant housing construction techniques. One of the best examples is India's *Dhajji-diwari* style in the Himalayan belt wherein the technique uses stones for lower storeys and a combination of bricks and timber for upper storeys [89]. To prevent landslides in Sri Lanka, locally developed stone walling techniques and the use of Pawatta plant as live fences are employed [8]. In Senegal, agricultural yields are optimised through the invention of micro dams – a hydroagricultural innovation by the communities that can retain water and impede drought for a few weeks [90]. In China, traditional settlements were built to be protected from storms through windbreaks, dense-alley patterns, courtyards, strengthened exterior walls, and local roof technologies [91].

Structural measures are a product of understanding the impact of disasters and identifying the physical remedies to counteract such impact to mitigate risks. As these measures are developed out of locally understood scientific principles in the absence of more formal ways of learning, aptly, these are local technologies that have shaped risk reduction strategies prior to more technical approaches. Similar to the hybridisation of early warning systems discussed in the previous section, the same phenomenon has also been observed for structural measures. Some discussions on LIK now include the integration of local and indigenous building techniques with contemporary strategies. For example, in Pakistan, a post-disaster reconstruction initiative relied on traditional character and form of structures but strengthened them with formal engineering interventions [92].

4.1.5. Livelihood-based adaptation

Disasters threaten not only the safety of communities but also their livelihoods. Scholarship on LIK presents a vast array of examples specific to agriculture. The most common agricultural practices across countries in response to different hazards include: crop selection based on the resistance to risks [6,60,93,94]; introducing new and/or diversifying crop options to optimise yield [79,85,90,93,95,96]; altering cropping patterns and structure [85,93,94]; relocating planting areas away from high-risk areas [9,66,90]; improving irrigation and water management systems [85,93,94,96]; and adjusting planting schedules [9,93,95,96]. Additionally, other farming schemes have been developed or adopted such as market gardening in rainy conditions alternating according to the seasons in Senegal [90] and floating agriculture to adapt to the persistent flooding in Bangladesh [85]. In Taiwan, communities release water in the fish farms and set up surrounding nets to prevent water and fish overflow for aquaculture-based adaptation strategies in response to flooding [6].

Communities also practice livelihood diversification – a strategy to secure more than one source of subsistence to sustain a living in the face of dynamic risks which threaten the primary source of livelihood. In Sri Lanka, fishers engage in collecting honey, rice cultivation, selling fruits, among others, to reduce main reliance on aquaculture-based activity and increase income options in adverse conditions [97]. Similarly, in the Philippines, some Aetas rely on combining and switching activities (cultivation, animal husbandry, etc.) while repeatedly changing their locations as a coping mechanism after the 1991 Mt. Pinatubo eruption [98].

The scholarship on LIK clearly points to livelihood-based strategies that are as dynamic as the risks communities face. It is evident from the examples that adjustments happen through living with these risks while finding ways to secure livelihoods rather than eliminating the risks upfront to revert to the usual livelihood setup under normal conditions. When lands are submerged, people innovate to farm on the floodwaters; when crops are susceptible to damages, farmers diversify their planting options. As hazards impact sources of subsistence, communities come up with livelihood innovations reflecting their resourcefulness amid disasters. These innovations happening on the ground reflect the complex socio-economic responses that they need to undertake to thrive and survive

in altered conditions.

4.1.6. Social cohesion

Transcending beyond individual actions are collective efforts by communities to pool their knowledge and resources in the face of hazards, either within established organisations or through informal social linkages and networks. We present social cohesion as an intangible asset that is activated in times of crisis [99], whether as an inherent part of a culture or existing within the day-to-day concept of sense of community. The common denominator lies on how different community members ultimately work together to prepare for or recover from disasters.

In terms of social cohesion imbibed within a culture, an example is from the *Sahis* of Puri, India. Communities rely on mutual cooperation to address communal problems, such as working together in response to calamities regardless of differences in economic status or social position (caste) [100]. Disaster recovery of a community in Bangladesh is being propelled by the help of *samaj*. It is a local-level traditional institution that bonds like-minded community members governed by customs and norms, apart from supports of other community organisations such as *madrasha* management committees, schools, etc. [86]. Beyond formally established community organisations like committees and traditional institutions, knowledge and practices still make their way through social ties and tight-knit networks. In preparation for flooding in Malawi, social networks are utilised to help community members stabilise houses, relocate livestock, seek temporary shelters, and rely on warning information from traditional leaders during community meetings [9]. In Japan, motivations for evacuation during the 2017 torrential rain in Kyushu were based on community discussions – made possible by good neighbourhood relationships – in lieu of timely disaster information due to power outages [101].

A breadth of other examples exists affirming how social cohesion manifests across communities, from customary support and resource sharing systems (see [56]) to neighbourhood-driven rescue operations (see [82]). From this review, we have observed the roles cultural settings and good neighbourhood relations play in activating this intangible asset. While these two are not the only precursors to social cohesion, they are prominent factors contributing to building a safety net to combat risks for communities undertaking collective actions.

4.1.7. Beliefs

The truths that communities believe in and hold as valid significantly shape their understanding of risks and hazards and thereby affect how they respond to disasters [102]. Discourse on beliefs linked to DRR prominently presents the idea that disasters are a form of punishment for transgressions, such as in Zimbabwe where the occurrence of hazards is attributed to being sinful or abandoning one's culture [12]. Beyond the concept of punishment, von Vacano & Schwarz [103] present related religious framings of disasters – admonishment and divine test. The former seeks to remind to improve one's faith, while the latter challenges the belief of a person to be proved through coping of the disaster. Meanwhile, in some communities, a divine entity is considered as the source of protection whom they can seek safety from hazards [104] and ask for guidance to recover after disasters [86]. Beliefs are also attributed to supernatural forces such as a case in Peru where a landslide is believed to be caused by a bull pushing the earth downslope [73], and in the Philippines where volcanic activity is associated with spirits [98].

We can see from these examples that beliefs can either give a sense of fatality among communities (with the worldview that someone is in control of everything, including the occurrence of disasters) or a sense of psychological safety (as faith to a central figure can give support and guidance in surviving disasters). This observation is consistent with the two impact pathways of Sun et al. [102] where they explain that beliefs have both constructive and harmful impacts. The former is believed to foster and promote disaster resilience individually and collectively as a social unit while the latter can inhibit the initiative of communities to cope with disaster.

4.2. Themes: Foci on how LIK has been studied in DRR

In this section, we present the foci of how LIK in DRR has been given attention in scholarship. The focus on LIK for risk reduction efforts started to spike during the mid-2000s. Such finding is consistent with Hiwasaki et al. [21] who note that scholars became

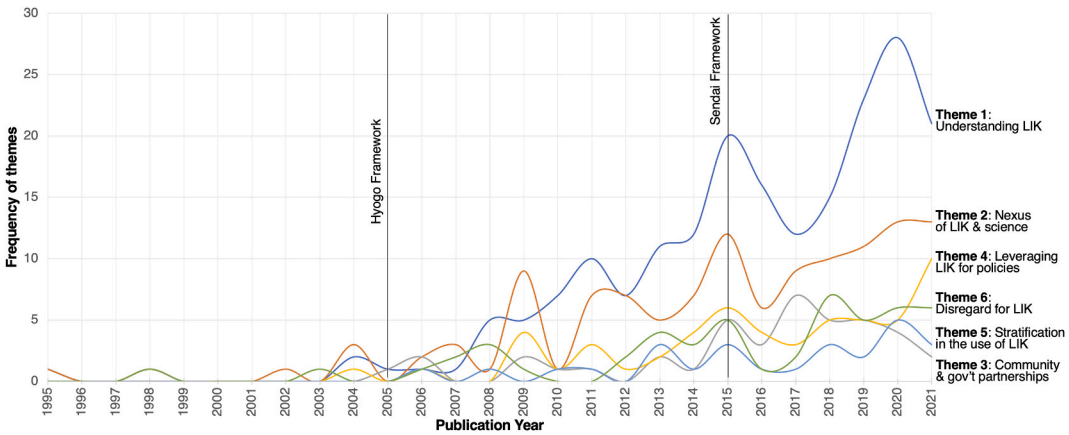

Fig. 5. Trend across the themes identified based on the frequency of publication reviewed in each year.

interested in the potential use of LIK in DRR after communities used their indigenous knowledge and coping practices during the 2004 Indian Ocean earthquake and tsunami. Unsurprisingly, most interest on this topic has been dedicated to understanding the knowledge and practices, including how they are used for DRR and how can they further be leveraged. Fig. 5 shows how primary LIK themes have flourished, and we discuss each of these themes in the following sub-sections.

4.2.1. Theme 1 – Understanding LIK: Knowledge construction, identification, and points of leverage

Risk can be understood by communities differently and may provide varied motivations to respond [67]. Several studies have explored how LIK is constructed as a form of knowledge for DRR. For instance, Swee [68] focused on the Australian tropics to understand how local cyclone knowledge is "assembled" and found that it comprises of heterogeneous parts – which include other knowledge sources apart from that of community's own risk perception – and are integrated in an ad hoc and complex manner. Every community interprets disasters in a localised way, and Bongo et al. [12] associate the varied interpretations to the concept of a "script" that needs to be well understood within local priorities and knowledge systems. Interactions of communities with their environment give rise to LIK. Examples include how bushfire risk perception emanates from the interaction of people, landscape, and objects [105] and how local practices of flood management in Myanmar have been shaped by the hydrosocial relationship among residents, institutions, and settlements [106]. Similarly, close relationships between fisher communities and their environment result in what Mulvany [61] call "flood imaginary" or the traditional mechanisms to understand and cope with the impacts of seasonal flooding in India.

To further understand LIK and gain insights into its role in DRR, there is a growing consensus among scholars to document the knowledge and practices, even to the extent of emphasising it as a clarion call [81]. Mutasa [107] argues that unless LIK is documented and preserved, its marginalisation will continue. Recognition of LIK helps sectors involved in DRR management acknowledge its importance [62] and preservation [108]. Documentation is also the first step to understand the principles behind how these local practices work in their own context to be more readily accepted and understood by others [21,109]. From here, points of leverage to maximise the use and recognition of LIK can be inferred. For example, Sharma [110] promotes capitalising on the local technologies of communities while Baumwoll & Krishnamurthy [111] suggest extracting common principles and transferrable elements from documented LIK to apply them as strategies to help vulnerable communities. If there is a prime association with how scholars have understood LIK, it is on the idea that since these assets are homegrown and have been used by communities over time, these knowledge and practices can help to enhance local-level resilience [6,100,112–115]. But documentation comes with risks as well, including how it can strip the contextual aspects of LIK [116]. When exposed to external stakeholders, the practices can also be taken advantage of. To this extent, LIK has been legally protected in some societies like in the Philippines where it is considered an intellectual property (see [7]).

4.2.2. Theme 2 – Nexus of LIK and science: Integration, validation, and management

DRR agenda have tendencies to juxtapose LIK with scientific knowledge. The former is understood in this study to be developed locally from community resources (e.g., disaster experiences, lessons handed down by elders, and local materials), while the latter is a knowledge sphere acquired through a formal evidence-based technical systematisation of information. Garcia et al. [117] explain that LIK alone is insufficient to reduce disaster risk, while scientific knowledge is devoid of the holistic picture to understand the local vulnerability context. Combining the two knowledge bases renders more precise information useful for decision making [117]. Additionally, communities with low literacy levels may find it challenging to understand technical concepts moulded on scientific principles and they may resort to customary knowledge [44,118]. Conversely, outsiders might encounter loss of translation when understanding LIK [58] because such knowledge systems are contextually embedded in a community's cultural setting. Scholars should thus continue to advocate for the potential benefit of combining LIK and science to create more robust systems (see [21,33,59,119]).

Several studies have focused on deliberate efforts to incorporate and integrate community risk perceptions and local spatial knowledge into geospatial technology – such as Geographic Information System (GIS) and Remote Sensing (RS) – to create hazard maps, vulnerability indices, and resilience assessments (see [58,66,72,73,120–136]). Other means of integration happen in post-disaster reconstruction where traditionally built structures are strengthened with engineering interventions. Examples include the "Building Back Safer with Vernacular Methodologies" initiative in Pakistan [92], the adoption of stabilised compressed earth blocks to traditional construction systems in India [110], and the material modifications introduced to *quincha* – a traditional structure in Peru – to improve its seismic performance [137].

Comparison and validation of the two knowledge bases have also attracted attention among scholars. The most popular focus is analysing how LIK of weather and climate trends conform with meteorological data [63,94,107,138–142]. There are also attempts to validate LIK through experiments. For example, Zhang & Nakagawa [143] examined the hydraulics and morphodynamics of *Bandal* structure, a traditional flood and erosion control technology, to understand how the design idea can have the potential to be integrated into contemporary engineering. In comparing the two knowledge spheres, Malone et al. [49] suggest the concept of "cross-validation" where it allows the two knowledge bases to converge and diverge, and where the limitations of each other can be addressed by strengths in the other.

However, the school of thought that LIK is inherently hybridised – that it co-develops with other knowledge sources – is gaining popularity. Lin & Chang [144], for instance, argue that LIK absorbs other knowledge sources instead of rejecting them, forming an involuted knowledge. Meanwhile, Lauer [20] explains that even isolated indigenous communities draw on the intersection of many knowledge systems which allow them to innovate. For example, in the Philippines, communities adopt typhoon warnings from broadcasted meteorological information combined with traditional forecasts based on environmental signs [4,145]. The reliance on

the integrated sources of knowledge to gain insight into impending hazards has also been observed in Malawi [9], Indonesia [19], Zimbabwe [146], Fiji, and Tonga [147]. These are evidences that even when there is no deliberate effort to integrate both knowledge spheres, LIK and scientific knowledge are already being informally combined on the ground by local and indigenous people. Such evidences support calls, like that by Pascua [148], to reject the artificial compartmentalisation of LIK and scientific knowledge bases.

4.2.3. Theme 3 – Community and government partnerships for appraising LIK

While communities have internally developed capacities to handle disasters, they still, however, need external assistance at times [149]. This need for external support can arise from limitations of local capacities. Thus, there is a need to integrate top-down (government-driven) with bottom-up (community-based) approaches [150] in responding to disasters, striking a balance between inputs from administrative authorities and insights from communities [15]. When government-initiated disaster management lacks sensitivity to local-level conditions, affected communities transform policies to respond to disasters better suited to their own circumstances [144].

To foster partnerships between communities and the government, McDonnell et al. [151] present the idea of "managed participation" as evident in the state-led, public post-disaster planning in the aftermath of Superstorm Sandy in New York. In this idea, integration exists between intra-community social ties ("horizontal") and extra-community relations with policy institutions and agencies ("vertical"). Ingham & Redshaw [152], meanwhile, encourage a paradigm shift from rescuer-victim dichotomy and instead embrace the concept that responding to disasters is a "shared responsibility". Vallance [153] sees local government as a recovery agent and an "architecture of engagement" – which pertains to the broad social connections being foundations of a rebuilding process – as an enabler to see both opportunities and needs of the affected residents. However, partnerships can be a challenge especially in communities where their traditional cultural fabric remains intact. In this case, communication and coordination with traditional leaders, village chiefs, or seniors can serve as the gateway to a meaningful rapport [154,155].

Examples of partnerships between community and government include: the establishment of village-level disaster committees in India [110,156] and Nepal [157] comprising of local leaders who partake in disaster risk planning and management; the transdisciplinary community-based DRR approach undertaken in China to complement the existing top-down system of the government [158]; the co-managed flood early warning system in Indonesia where it serves as a platform of interaction between the community and the government [64]; and, the inclusion of LIK by DRR authorities in tackling the risks imposed by an Icelandic glacier [32].

4.2.4. Theme 4 – Leveraging LIK for policy recommendations, programme development, and lessons learned

Acknowledgement of LIK is not sufficient to leverage it for DRR. There needs to be an impetus to translate ideals well presented in literature into practice. This theme presents those that leverage the merits of LIK for policies, programmes, lessons, and other insights which can transform theory to practice. For instance, Dube [125] proposes an inclusive, multilevel wildland fire management in Botswana and recommends drawing upon LIK to co-determine temporal risk assessments. In analysing external stakeholders' attitudes towards engaging LIK to DRR, Šakić Trogrlić et al. [44] present enhancement pathways suggested by formal DRR practitioners. These include improvement of community engagement, documentation, validation, and dissemination of LIK, integration of LIK with science, and empowerment of communities to use their LIK. Meanwhile, Griffin & Barney [19] recommend that when knowledge sharing between experts and communities already exists, there should be a departure from dividing between knowledge systems, and instead focus on balanced sharing and identifying existing rapport.

Projects and programmes have also been devised to leverage the merits of LIK for DRR. For example, to enhance disaster prevention capabilities among children and assist engagement in the reconstruction after the Kumamoto earthquake in Japan, an educational programme was developed wherein knowledge based on the local historical experiences served as a starting point [159]. In devising evacuation operations, agility that could save more lives was achieved by incorporating local knowledge that provides contextualised information such as the shortest routes [160]. There have also been projects that draw on historical lessons to commemorate disaster events, such as installing plaques that can positively reinforce disaster awareness [161].

Leveraging LIK for policies, programmes, and projects provides a conduit on how the knowledge assets can be mobilised in the developmental realm. However, as LIK is place-based and is emergent within a localised context in which it belongs, there are considerations when extracting their value for risk reduction purposes. Generally, these considerations can be echoed from Kelman et al.'s [162] principal takeaways in appraising LIK, which include: (i) understanding the context and (non)transferability of the knowledge system; (ii) fostering trust and self-help by working with the knowledge that is already acceptable to the community; and (iii) acknowledging heterogeneity as differences do exist within communities.

4.2.5. Theme 5 – Stratification in the use and access of LIK

With LIK having social, economic, political, and environmental dimensions, its access and use are expected to be "nonlinear" and stratified. Hence, discussions of LIK in DRR should not discount such dimensions. Trogrlić et al. [9] explain that due to intergenerational and gendered differences, there remains an unequal distribution and access of LIK within communities. This theme highlights the stratifications of LIK that are emergent in scholarship. We focus on presenting how demographic factors affect the use and access of the knowledge system, and not about the inequities that these factors bring to communities.

Due to the traditional roles associated with men and women in most societies, gender continues to be a significant factor in the stratification of the use and access of LIK. Women are known to have a wide grasp of LIK due to their exposure to daily activities [59] and, alongside seniors and traditional leaders, are regarded as custodians of the knowledge system [163]. In Gauteng, South Africa, mothers are known to transmit local knowledge and techniques to their children revealing their foundational role in the promotion of LIK and its awareness [163]. Women have also been mostly known to help ensure food security in preparation for disasters in some communities as they are usually more familiar with indigenous food preservation techniques [4,164]. In some cases, women have been

shown to have a higher level of risk perception or disaster awareness compared to men [120,165]. In other contexts, men perceive climate variability better as it impacts the crop yields that they attend to [141].

Age also stratifies access to LIK for the apparent reason that senior members of a community have more disaster experiences and have often gone through several hazard events allowing them to acquire firsthand knowledge [166,167]. Social class has also been shown to affect disaster awareness with less privileged community members exhibiting lower risk perception [168] though this can be the result of societal marginalisation. Meanwhile, urban residents tend to have lower levels of local knowledge compared to rural residents who have most likely developed a sense of community and place attachment [169]. Lastly, occupation informs access to specific LIK, such as when fishers become familiar to forecast hazards based on water behaviour due to their close interaction with the environment [166,167].

4.2.6. Theme 6 – Disregard for the potential use of LIK

Lambert & Scott [170] have emphasised that as early as the mid-1990s, LIK was already acknowledged in disaster-related multilateral agreements but DRR strategies focused on the resources and assets of indigenous people remain challenging to implement. Among the contributing factors include state-sponsored or endorsed racism, historical isolation, ongoing marginalisation, and institutional inertia. This disregard for the potential use of LIK for effective DRR remains pronounced and can be explained by two broad and dominant influences: the persistence of scientific hegemony and the inherent technocracy among institutions and governing bodies.

With influential practitioners from global DRR organisations mostly being educated in scientific-based institutions [171], the mindset that science is more equipped than LIK in preventing risks continues to infiltrate DRR practice. According to Howitt et al. [172], "key institutional structures continue to privilege discourses based on scientific and administrative expertise over locally contextualised knowledges, and to discount or dismiss social and cultural dimensions of risk …" (p. 52). The perception that outside, expert-led knowledge is superior disempowers communities and may damage their local institutions [173]. Ironically, the development community – which has boosted the appraisal of LIK in literature – implicitly conveys a general attitude that LIK is a backward

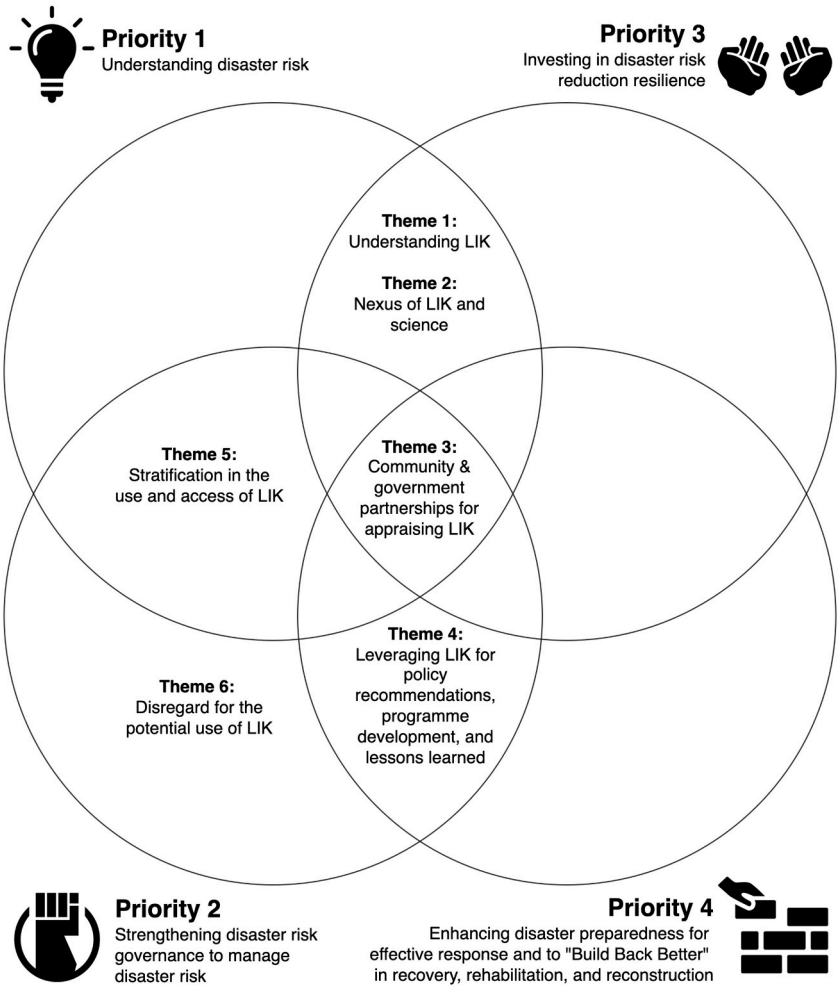

Fig. 6. Themes within the sendai framework.

form of knowledge, hence its effectiveness is questionable [44]. Similarly, practitioners often advocate the value of LIK whilst maintaining a dominant science-based stance to improve their image and avoid criticism [174]. Outright examples of disregard for LIK have been demonstrated. For example, in the Philippines, the Department of Science and Technology's preference is (somewhat obviously) science-based DRR strategies as LIK is a challenge to be incorporated into programmes when a technical working group is comprised of scientific experts [7]. Similarly, in Chile, the social memory and local historical records have been rejected by the Scientific Technical Committee due to their un-scientific nature in diagnosing a seismic crisis [175].

Technocracy has also contributed to the disregard of LIK. Disaster management carried out by governments, external institutions, and other organisations tends to exclude communities [73,133,144,176–179]. This approach has exacerbated community's exclusion with barriers such as weak capacity among community members to uphold their LIK at district and national levels, and the lack of institutional support to maintain a rapport between LIK holders and formal DRR practitioners [133]. As a result, technical-solution-oriented development is commonplace and the social, political, and cultural contexts of disasters have been taken out of context [113,180], sidelining the knowledge of locals and indigenous people for effective disaster management. In worst cases, some NGOs have been observed to abuse relationships with communities to leverage their objectives [60] or they operate within predefined frameworks thereby excluding potential contributions of communities [166].

4.3. LIK within the global DRR framework

The Sendai Framework for Disaster Risk Reduction seeks to advance local, national, regional, and global efforts to prevent new risks, reduce existing risks, and increase resilience, replacing the Hyogo Framework for Action in 2015 [24]. The Sendai Framework promotes LIK to *complement* scientific knowledge in disaster risk assessment and policy and programme development. However, the word "complement" alone implicitly discounts how other sources and interpretations of knowledge can be at par with more formal ways of knowing and understanding risk reduction measures. We refer to this as an embryonic recognition of LIK, which is unsurprising since there has been an observed shift away from valuing local community input towards technological advancements across the most recent global frameworks [43] (see Section 2).

In this study, we progress the Sendai Framework by analysing how the priority areas of action are captured in the current understanding of LIK in the DRR body of knowledge (see Fig. 6). In doing so, we endeavour to understand how the priority areas coincide with attention in scholarship, or the lack thereof. We discuss below each of the four Sendai Framework priority areas along with how the extracted themes from the review align to these. From here, we offer our recommendations based on the common messages conveyed across the literature to help realise the implementation of the global framework's priority areas.

4.3.1. Priority 1: Understanding disaster risk

Priority 1 of the Sendai Framework focuses on understanding the multi-dimensional characteristics of disaster risk [24]. To achieve this at the national and local levels, the framework suggests disseminating disaster risk information in appropriate formats to decision-makers and at-risk communities. The need to understand LIK (Theme 1) thus has relevance to how communities take actions autonomously or in partnership with stakeholders. Priority 1 further promotes that LIK should complement scientific knowledge for risk assessments, policymaking, and programme development (Theme 2). Numerous studies have adopted the integration of LIK with geospatial technology and this is well aligned with the Sendai Framework goal to "enhance measurement tools, and the collection, analysis, and dissemination of data without sidelining each of the knowledge spheres". Cross-sectoral collaboration, cooperation, and dialogue in understanding risk are also well highlighted under Priority 1 and this can be linked to the partnerships discussed in Theme 3. Risk, being multi-dimensional, co-exists within a broader social fabric and those who are directly affected should not just be the sole actors to address it. While there is much alignment of the Sendai Framework with literature, absent is nuance in who holds LIK. The framework adequately draws attention to the need to disaggregate social and demographic factors (such as age and gender) but falls short of recognising that LIK is stratified and not homogenous (Theme 5). These shortcomings discount acknowledging the dynamics in how different members of a community use and access their knowledge resources.

4.3.2. Priority 2: Strengthening disaster risk governance to manage disaster risk

Priority 2 promotes the effective and efficient management of disaster risk based on clear vision, plans, competence, guidance, and cross-sectoral coordination [24]. If understanding risk requires partnerships, risk governance should forge them. The role of government to help local and indigenous communities to realise their knowledge assets has been highlighted in Theme 3. While governments are not the only institutions that support the implementation of instruments relevant to DRR, policy recommendations that arise from LIK presented in Theme 4 will remain unutilised unless there is motivation to advance these within legal frameworks. Strengthening risk governance should also consider the problems that exacerbate the vulnerability of communities. Unequal access to knowledge within communities (Theme 5) is one such dilemma for capacity building efforts outlined in the Sendai Framework. There have also been both deliberate and unconscious efforts by technocratic bodies to disregard the potential use of LIK for DRR (Theme 6). Tacitly, technical-solution-oriented developments remain to be the dominant approach in "reducing risks" and these most often ignore how communities respond to and prepare for disasters.

4.3.3. Priority 3: Investing in DRR for resilience

Priority 3 emphasises the need to invest in both structural and non-structural measures to prevent and reduce disaster risks [24]. As highlighted in Theme 1, there are a plethora of locally developed strategies that communities use to face hazards which include those that are intangible (e.g., forecasting abilities, risk perceptions, social cohesion) and tangible (e.g., seismic-responsive dwellings, soil erosion and flooding technology). These "homegrown" strategies are investments that DRR practitioners can utilise. These assets are readily available and acceptable to communities. However, while these measures are promising, they are not without limitations.

Integrating these into the scientific domain (Theme 2) can be a way to emphasise the strengths of these practices and advance cooperation among academic, scientific, and research entities in developing risk reduction interventions. Under this priority, there is again a need to echo the importance of community and government partnerships (Theme 3) as it is understood that to leverage such investments to reduce risks and mainstream related activities, governmental support will substantiate these efforts.

4.3.4. Priority 4: Enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation, and reconstruction

Priority 4 highlights strengthened disaster preparedness for response, actions to anticipate events, and capacities for response and recovery. Additionally, Priority 4 emphasises "building back better" as an opportunity in the recovery, rehabilitation, and reconstruction phases [24]. The concept of building back *better* references lessons learned from past actions. Under Theme 4 developed in this study, extensive literature points to enhancing preparedness and capacities to build back better by leveraging the knowledge assets of communities. However, the mention of "adoption of policies, plans, and programmes" again shows a need for community and government partnerships (Theme 3). The Sendai Framework underscores a need for guidance instruments (e.g., codes and standards) to support coordinated action for disaster preparedness and response as well as to facilitate exchange of information for policy practice and programmes for post-disaster reconstruction.

5. Limitations

While this study aimed to be as inclusive and comprehensive as possible to capture all pertinent documents to reflect the state of knowledge, we acknowledge that some documents of interest may not have been captured by the search string. Due to the plurality of terms in DRR literature, some authors may have discussed LIK and disasters but used different, less common terminologies. Additionally, these terms could have also been implicitly represented in other discussions. The criterion to exclude non-English documents does omit important insights but was necessary in favour of what we can only interpret. This is potentially shown in the skewed geographical representation of the included studies, with fewer documents from low-income countries. Lastly, we only focused on peer-reviewed articles to understand the scholarly attention. Thus, the exclusion of grey literature misses how organisations and institutions might have depicted LIK in their technical reports, working papers, and other non-scholarly documents.

6. Conclusions

The discourse on LIK highlights a plethora of practices that communities possess and use to prepare for, mitigate, respond to, and recover from the impacts of disasters caused by natural hazards. We systematically reviewed 325 documents that were qualitatively coded to identify what practices constitute LIK, patterns in how it has been studied, and how our current understanding of the knowledge system fits to the Sendai Framework.

We elicited a wide range of LIK developed on the ground, from hazard forecasts to anticipatory measures, which is shaped by social cohesion and belief systems. From both fieldwork- and non-fieldwork-based studies, we found that low-income countries are less represented in the scholarship compared to middle- and high-income countries. We also found deliberate attempts to forge knowledge and power spheres, such as the acknowledgement of the hybridisation of both LIK and scientific knowledge in understanding risks, or the collaborative efforts between experts and local communities in mapping hazards. In the Sendai Framework, the general recognition of LIK is still embryonic, although we see how the current understanding of LIK in scholarship aligns within the priority areas of the framework.

So, where does LIK in DRR go from here? First, our holistic synthesis hints the geographical skewness of where LIK has been (under) studied. While numerous strategies and practices emerged from publications, other vulnerable communities holding a great amount of LIK from less popular regions do not share the limelight. We encourage shifting focus to these less represented groups to understand how they manage the impacts of disasters in lieu of access to formal DRR support which are beyond their reach in most cases. Second, we welcome the hybridisation of knowledge and power spheres as they strengthen risk reduction measures by relying on various sources of knowledge and information. However, we are compelled to mention how LIK can be at risk of being exploited at this amalgamation of knowledge systems due to how they could be misunderstood and misused when taken out of their place-based and cultural contexts. Thus, there should be institutional safeguards to when these are being used in conjunction with other knowledge bases. Third, our framing of LIK to the Sendai Framework priority areas identifies alignment and ongoing gaps in LIK applications in DRR. Along this, we challenge future policymakers to consider crafting the position of LIK in future global frameworks as a knowledge system existing on its own right, and not just adjunct to scientific knowledge as how it is currently being represented. Last, the sustained scholarly attention of LIK should inform a collective identity of the knowledge system out of the rich and vast representations in DRR literature. Such identity strengthens its character in the DRR practice and policy environments useful to further progress its recognition and protection amid threats such as rapid urbanisation and persistent technocracy.

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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.

Data availability

No data was used for the research described in the article.

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