The promise of a “people-centred” approach to floods: Types of participation in the global literature of citizen science and community-based flood risk reduction in the context of the Sendai Framework

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**ABSTRACT**

Floods are expected to become more intense and increasingly frequent over the coming years. Over the last few decades, scholars, policy makers and risk managers have been gradually acknowledging that community-based initiatives can represent a promising alternative for addressing the hazard of floods at the local scale. In the context of the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR), this article presents a systematic literature review of the recent global body of literature on the topic. This work analyses 40 articles published over the last five years to identify the types of engagement allowed in the projects and to discuss the emerging debates in the field since the establishment of the SFDRR. The literature review interrogates where these approaches are being developed and how community-based approaches have been supporting the achievement of the SFDRR targets. The review shows that a growing body of literature has been applying community-based disaster risk reduction (CBDRR) and citizen science methods in order to respond to the call for a more people-centred approach towards flood risk reduction. The SFDRR, is particularly relevant in the context of vulnerable communities such as the residents of informal settlements, which have historically been disproportionately affected by floods. The article then provides an original contribution to the field by documenting and reflecting on the firsthand findings of a long-term community-based program assessing flood risks conducted within the Revitalising Informal settlements and Their Environments (RISE) program. The article outlines the implementation, operation and initial findings of the project, which involved community members in the documentation of flood levels in informal settlements in Suva, Fiji and Makassar, Indonesia between 2018 and 2020. The findings from the case study suggest that approaches involving communities in flood monitoring can, beyond facilitating flood documentation, unlock additional risk reduction benefits such as enhancing social capital and facilitating risk communication. The conclusions highlight that, similar to RISE’s flood monitoring project, several other community-based initiatives have been developed all over the world. While these initiatives vary significantly in the degrees of community participation and their methods, most of the literature agrees that these emerging methods are considered particularly promising in terms of improving disaster knowledge and awareness when community members participate in disaster risk reduction. The review of this body of literature, however, indicates that more research is needed to examine how social capital as well as cultural and political aspects can be harnessed and strengthened to play important roles in the response to floods.

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1. Context and background for the literature review

The Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) was established to respond to a global context characterised by disasters becoming increasingly frequent and intense all over the world [77]. The SFDRR suggests that “there has to be a broader and a more people-centred preventive approach to disaster risk” and that special attention and support should be directed to “developing countries […] to augment domestic resources and capabilities” in terms of disaster risk reduction [77]. It also advocates for a “multi-hazard and multi-sectoral” practice as an alternative to more unidimensional centralised methods traditionally used to map, monitor and respond to disasters [77]. The recent literature in the field, however, indicates that the political, technical and practical challenges of this agenda might demand a significant revision of the methods traditionally used to address disaster risk all over the world. As a response to this call for action, several authors have been arguing that the popularisation of community-based initiatives, including citizen science and community-based disaster risk reduction (CBDRR) projects, might be essential to achieve the SFDRR’s agenda [1,49,79].
Institutions and authors have suggested that “citizen science” approaches have a unique potential to contribute to environmental monitoring and extensive data-collection efforts [5,22,80]. However, the literature on citizen science reveals that these methods have been historically questioned due to concerns with the accuracy and completeness of the data generated [10,13,20,41,46]. Moreover, there also seems to be little consensus on the potential of engagement offered by these methods in terms of actually creating opportunities for communities to participate meaningfully in discussions historically considered technical realms [8,27]. Revisiting these debates, this article seeks to interrogate the recent literature of community-based flood risk reduction in relation to these claims.

This review aims to investigate to what extent community-based methods can contribute to achieving the goals posed by the SFDRR in the context of floods, the most common of all types of disasters [74]. In doing so, this article questions the types of participation documented in the recent literature and attempts to ground this discussion with the exploration of a new case study. The discussion contemplates questions such as: are community-based approaches addressing the challenges of resources and capabilities in “developing countries” and engaging vulnerable communities such as residents of informal settlements? What kinds of methods have been used to engage community-members in flood risk assessment, monitoring and mitigation? In which stages and conditions are community-members contributing to disaster risk reduction? This article, therefore, seeks to provide a systematic global review of the recent literature on CBDRR and citizen science initiatives dealing with floods and investigate (i) where are community-based initiatives being developed, (ii) which approaches have been used to facilitate community-based disaster risk reduction efforts and (iii) what is the role of community-members involved in each of these initiatives.

To support this investigation, the next section will briefly review how the risk literature has understood communities throughout time and how their role in the process of addressing risks is differently perceived by disciplines and researchers.

2. The origin of community-based approaches and citizen science

The pioneer “systematic classification of risk perspectives” elaborated by the German sociologist Otwin Renn is still one of the most influential works dedicated to classifying the different disciplines and approaches towards risk [58]. Ranging from actuarial applications to debates in the field of cultural risk theory, this seminal classification offers significant insights into how fields such as epidemiology, safety engineering, economy, psychology or sociology interpret risk differently. In one of the sides of the spectrum, Renn locates actuarial, epidemiological, safety engineering and economic approaches that employ risk as a framework for assessing uncertainties, allocating resources and supporting decision-making. In the other side of the spectrum, psychological, social and cultural approaches understand risk as a framework for investigating social fairness, risk communication, political legitimation and cultural identity [58]. These different perspectives have since evolved into traditions leading to a diverse and interdisciplinary body of literature that today influence what came to be known as Community-Based Disaster Risk Reduction.

The consideration of communities within risk frameworks can be traced back to early works that acknowledged the importance of considering human perception and social processes in the realm of risk [33]. Some of these early works have emerged, for instance, from the foundational work of Slovic on the psychology of risk using psychometric methods [66]. Originally, these approaches served to respond to debates in the risk arena such as who decides on the tolerability of risk and which criteria are appropriate to evaluate the potential damage from uncertainties [14]. More recently, however, these perspectives have expanded in depth and scope and have re-vibrated in literature addressing the experiences of local communities facing environmental hazards such as earthquakes and floods [29,65]. This body of knowledge recognises that communities have always played an important role in disaster recovery and preparedness [24,34,63].

Emerging from a different tradition, the concept of citizen science is also based on the understanding that communities can be valuable agents in the process of understanding and monitoring disasters. The idea of citizen science can be traced back to earlier authors that described the notions of “people’s science” [84] and “civic science” [43] as frameworks for engaging citizens in activities analogous to those conducted by scientists. As the model developed over the ensuing years, approaches diversified and adapted to other disciplines resulting in a body of literature that encompasses a variety of terms and methods. The most often used terms include “community-based monitoring” [9], “volunteered geographic information” [25], “crowdsourced data” [44], “community science” [6] and, more notably, “citizen science” [23].

Within the specific literature of risk, these concepts can describe substantially different models based on distinct methods and oriented by different goals. In practice, the concepts of citizen science and community-based monitoring are used to describe initiatives that encourage community-members to contribute to a scientific database by sharing evidence or reporting on a particular phenomenon. Similarly, the term citizen science has been used in the literature to refer to projects in which scientific activities are conducted by non-scientists, commonly under the supervision of a scientific body or practitioner [22]. To achieve the social potential of citizen science, however, it is important to discuss the degree of the engagement of community-members in each kind of project.

Over the years, researchers have increasingly been investigating the roles played by participants in citizen science projects beyond contributing to data-collection [8]. Several authors throughout the years have attempted to classify the types of participation allowed by the different models of citizen science projects [21,39,54]. Among them, an influential literature review of citizen science published by Haklay provides a useful description of the different types of involvement possible in the context of citizen science [21]. Based on his descriptions, this article will define in simple terms some of the typologies of citizen science projects as:

(i) “Crowdsourcing” is the practice of using citizens as sensors contributing to volunteered computing
(ii) “Distributed intelligence” is the practice of inviting citizens as basic interpreters contributing to volunteered thinking
(iii) “Participatory science” is the practice of involving citizens in the problem definition and data collection
(iv) “Extreme citizen science” is the practice of collaborating with citizens in the problem definition, data collection and analysis

While not universally applicable, the categories proposed by Haklay will serve as a framework to examine the participation of citizens in different projects in this literature review. While not all of these categories are commonly found in the fields of hydrology and flood risk reduction, they suggest that community participation can, at least theoretically, deeply incorporate citizen’s perceptions and local knowledge in the practice of monitoring floods at the local scale. As often agreed among authors, the roles played by citizens can be drastically different in different citizen science projects and, therefore, adopting these initial definitions will facilitate the analysis of the literature recently published on the topic. The next section will further investigate how the practices of flood assessment, monitoring and response have invited citizen participation throughout the years.

3. Literature review: community-based approaches and citizen science in the flood literature

This section introduces the background and scope of the literature review presented in this article. To support the arguments discussed below, it revisits the history of how citizen science has been applied to projects monitoring and mapping floods. The next paragraphs will discuss what is already known about the applications of citizen science and community-based approaches to flood risk reduction.

In the field of hydraulics and hydrology, citizen science and other related community-based approaches have been used to address water-related issues for several decades. In 1977, a work published by Wisner...
and others highlighted the potential of existing “systems of understanding” and proposed ways for “people’s science” to be considered in the field of disaster studies [84]. A literature review from the early 1990s documented a significant increase in the involvement of citizens in water-related projects between 1988 and 1992 [35]. Over the ensuing decades, the emergence of telecommunication and information technologies such as the internet and smartphones opened new possibilities for the participation of citizens in the generation of scientific hydrological datasets [73]. Since then, citizen science approaches have gradually become popular in flood risk assessment often by providing affordable and well-distributed data to calibrate probabilistic models [62].

Often following the safety engineering approach and contributing to probabilistic models, citizen science has been recently used for flood data-collection purposes including to complement the lack of historical flood references or to support modelling in data-poor ungauged catchments [25]. Over the last few decades, however, some works started hinting to the possibility that community-members could be involved in disaster risk reduction in other roles beyond contributing as data collectors [27]. Some works based on more social and cultural perspectives towards risk suggested, for example, that considering the social aspects of risk is essential for improving communication and for enhancing preparedness in the age of internet and social media [37]. This understanding has triggered a renewed interest in cultural and sociological approaches towards floods [38] indicating the need for further investigations on the cultural role that communities could play within disaster risk reduction projects.

Following the tradition of safety engineering, recent applications of the probabilistic approach towards risk have been primarily concerned with collecting data through sensors and satellite imagery which is then translated into usable records for flood modelling [51]. Given the concerns with data validity and accuracy to support these models, the involvement of communities in systematic flood monitoring approaches is still incipient in this field. Some studies, however, suggest that community-based approaches to flood documentation are expected to cover some of the limitations in terms of “observational inputs, forecasts, and resolution” that affect sensors, satellite images and hydrologic models [30].

The application of these probabilistic approaches has been documented in a quickly growing body of literature. A comprehensive literature review conducted in 2019 revealed that most articles on the topic were published after 2014 [62]. This review, focused on probabilistic flood risk approaches, has classified citizen science and crowdsourcing in the context of pluvial flooding within four types:

(i) applications during flood occurrences (such as locating floods and assessing the intensity),
(ii) applications post-flooding (such as assessing damage),
(iii) applications for flood modelling (including to support the development and validation and models), and,
(iv) applications for flood management and early-warning (including the integration of multiple data sources).

This classification is based on the literature developed over the last few decades and shows that while community-based approaches are still controversial in the field of probabilistic risk approaches, they have been used to support multiple different applications. Beyond contributing to probabilistic studies, participatory experiences in watershed modelling have been reported now for more than a decade [78]. More recent investigations show that there is evidence that citizen science can substantially facilitate data-collection and consequently, improve the modelling and understanding of catchment responses to rainfall [69]. While these approaches still suffer from a lack of acknowledgment and a general reticence from researchers used to more established methods [50], they have been increasingly recognised in international policy documents. Recommendations from both the Hyogo Framework for Action 2005-2015 and the Sendai Framework for disaster Risk Reduction 2015-2030 advocate that citizen science and CBDRR frameworks represent significant alternatives for successfully managing disasters in partnership with local stakeholders [75,77].

While it has been proven that community-members can effectively support data-collection within probabilistic risk approaches, it is also expected that citizen science would contain additional awareness and engagement benefits [2]. These benefits have been mentioned multiple times in recent literature reviews on the topic which examines how flood assessments have been utilizing crowdsourcing or citizen science approaches [62] and what technologies have been used for this purpose [48]. None of these reviews, however, have interrogated the literature in relation to the degree of community participation in flood assessment or monitoring projects.

Inspired by authors who investigated citizen participation in other fields [10,39], this review seeks to understand what roles are played by the communities in each of the identified publications. Some reviews discussing citizen science applied to environmental assessments, for instance, have differentiated between projects where citizens just provided data to a central decision-maker and projects where the community is involved in the decision-making and planning [39]. So far, literature reviews in the field of community-based flood assessments have not directly investigated the extent to which communities have been actively involved in all the stages of the study nor their effects in promoting more equitable and fair access to disaster risk reduction.

In this context, this article asks: Have citizen science projects contributed for a more people-centred perspective towards disasters since the SFDRR was established? Building up from the findings of previous reviews, this article examines the recent literature of the field to answers this question. The following subsections present first the scope and then the findings from the systematic literature review of recent articles describing the use of these approaches to support flood-related disaster risk reduction.

3.1. Scope of the literature review: Identifying the publications in the field

This review looked at published works to draw lessons from recent case studies on community-based approaches contributing to the broader field of flood risk reduction. In this literature review, the term disaster risk reduction is broadly employed to refer to any initiatives analysing and managing the causes of disasters including the reduction of vulnerabilities and enhancing preparedness [76] including the approaches that came to be known as community-based disaster risk reduction [64]. In order to map the field of community-based initiatives applied to address floods, the scope of this review was expanded to include activities more broadly involved in the assessment, monitoring, prevention or mitigation of floods.

The search for journal articles published between 2015 and 2020 was conducted on Scopus, Web of Science and Google Scholar and looked at all articles that contained the word “flood” (and variations such as flooding or floods) in the title and either the terms “community-based”, “citizen science” or “crowdsourced” (and variations such as crowdsourcing) in the title, abstract or keywords. Then, I analysed all the peer-reviewed journal articles within the first 100 entries from Google Scholar as well as the 92 articles returned from the search on Scopus and the 114 articles found through Web of Science. They were then filtered to identify rigorous publications describing community-based disaster risk reduction initiatives leading to a final group of n = 40 articles. These were then coded and analysed in order to identify the type of participation in each project and, therefore, situate the project in relation to the broader field of community-based flood risk reduction over the recent years.

I acknowledge that other significant water-related works involving community-based approaches might have been left out of this analysis for not explicitly mentioning floods. Some of these publications discussed disasters or watershed modelling, but did not focus on floods specifically [69,71]. Others discussed relevant aspects of citizen science - for example the involvement of indigenous communities - in other applications, such as water quality assessments [83]. While these are relevant publications in the field of citizen science and community-based approaches, they were not included in the final review because they did not emphasise investigations on how floods have been monitored, assessed or mitigated by community-based initiatives.
Therefore, this literature review is only analysing peer-reviewed publications that included the description or demonstration of approaches for assessing, monitoring, preventing or responding to floods using participatory or crowdsourcing methods. While similar to other methods commonly applied to monitor floods using images uploaded to social media [15], one crowdsourcing study was not considered in this review for not involving community-members in any stage of the risk management process [51].

Given the search criteria, it is important to note that this review only captured literature published in English language.

This review aimed to identify and compare already implemented and tested approaches involving community-members in the process of addressing flood risks. As such, there was particular interest in mapping the approaches that involved citizens or data generated by them in the process of documenting water levels, flood frequency, duration or intensity for disaster risk reduction including planning and decision-making purposes. This investigation served as a basis for comparison and situated the analysis of the community-based flood-monitoring project discussed as a case study later in this article. While this is not an exhaustive analysis of all peer-reviewed literature on the topic, it was designed to be a representative map of the current field of CBDRR applied to floods at the five-year anniversary of the SFDRR.

3.2. Discussion: distribution and typology of flood-related risk reduction and citizen science projects

The SFDRR recommends that developing countries deserve special attention in terms of disaster risk reduction [77]. As a starting point for this review, this section examines where the projects described in each publication were developed. Beyond investigating which countries were publishing the research outcomes, this investigation aimed to identify the countries where the initiatives were being conducted. This information is important to reveal where the projects were operating and under which conditions the communities were potentially being engaged in flood assessment, mitigation and monitoring.

The review shows that these initiatives have been developed all over the world as the 40 articles covered 25 countries in all continents except for Antarctica. The articles were categorised and ordered in Table 1 according to the year of publication, from the most to the least recent among each group.

The distribution of the case studies described in the recent literature show that both the Global North and South have hosted community-based flood assessment or risk reduction initiatives. International collaborations, as recommended by the SFDRR [77], have been well documented in the peer-reviewed literature. All publications clearly specified the countries where the case studies were conducted, even in the articles that focused on demonstrating methods for analysing crowdsourced data in flood analysis. The only exception was a study published by Portuguese researchers demonstrating the use of deep neural networks for crowdsourced photographic interpretation which used flood photos from European datasets that were not country-specific [53]. Several articles (18) included authors affiliated with institutions from more than one country. Most of the publications included at least one researcher from at least one of the Countries studied in the publication (34). The exceptions included only six articles describing case studies in Senegal, Mexico, Belize, Togo and Denmark and the previously mentioned study that used an unidentified dataset [3,16,19,36,53,61]. Most publications, particularly the ones focused on demonstrating methods, have described case studies in specific countries that could be replicated in other contexts.

The table below shows the countries in which the case studies were developed and groups them in project with similar characteristics in terms of citizen participation typology. The four main groups identified are loosely related to the participatory classification of citizen science projects proposed by Haklay [21]. These groups are further explained in the following paragraphs.

The first category of approaches identified in Table 1, includes a diverse group of case studies describing local solutions emerging from the deep involvement of community-members in all stages of the disaster risk reduction process. From the 40 articles, eight have described CBDRR initiatives that were created and managed by the communities directly. Many of these approaches have been described in the literature of local flood adaptation [7,11,59], but might be considered too “unsystematic” for more traditional definitions of CBDRR.

The second category includes several studies developed by external programs that sought to involve community-members in the production of data or risk reduction frameworks. Seven articles reported case studies describing this category of community-participation. These studies often acknowledged that communities could be directly benefitted by receiving the results of the CBDRR process. Among them, one case study in Nepal described a program based on improving risk communication that was not initially created by communities but that is currently operated by community-members. This community-based early warning system trains communities to communicate high water levels to other communities downstream in the same watershed [68]. The authors indicate that this project has significantly improved local flood risk mitigation strategies by allowing residents to take protective measures in advance of flood events.

A third group of publications includes research on CBDRR approaches that involved community-members in the production of evidence but that considered that the results were of interest primarily to traditional decision-makers such as government and other researchers. While many of these studies highlighted the potential value of the results to communities and to society in general, the text did not demonstrate that communities have currently been directly benefitted from the achieved results. While community members were not intended to be the target audience for several of these studies, in others there is evidence that communities were not involved in decision-making due to challenges when communicating findings.

The final group of articles is also characterised by CBDRR approaches that frame community-members as sensors [21]. These projects should also be defined as crowdsourcing according to established definitions. Three of these case studies [32,67,85], however, were not primarily described by authors as crowdsourcing initiatives showing that there is still lack of consensus on the terminology used in the field. In addition to fulfilling the requirements to be considered crowdsourced projects, these approaches have also been characterised by initiatives in which community-members are not aware that they provided data. In this case, additional benefits in terms of disaster awareness and communication (that exist in varying degrees in the other groups) are non-existent if the results are not widely distributed.

3.3. Discussion: types of participation in citizen science projects in the context of the Sendai framework

As expected, the review demonstrated a clear distinction between probabilistic risk approaches that engaged with “crowdsourced data” and approaches with varying degrees of cultural and social appreciation described as “community-based” or “citizen science” studies. Converging with the terminology used by Haklay, crowdsourcing projects have in most cases demonstrated an interest in developing a system or model in which citizens contributed as sensors while participatory or community-based approaches have opened more opportunities for the participation of citizens in the formulation of the problem and even in the analysis of the findings [21].

Similarly, the classification of roles performed by the community presented in Table 1 is not intended to judge the efficacy of the projects. Instead, this categorisation intends to describe the degree of community participation in projects following different types of approaches. While evidence suggests that decision-makers should try to achieve the highest possible community participation for every kind of approach [21], it is important to acknowledge that this involvement is limited by the conceptual and practical characteristics of each project. For instance, projects dedicated to validating flood models rarely offer results that are directly accessible to the affected community. While this does not mean that these projects are less valid, it suggests that they offer less opportunities for community participation. The maximum
Table 1
Categories of community involvement, references and locations of the case studies. The categories emerged from the analysis of the publications and is inspired by the classification of citizen science approaches proposed by Haklay [21].

<table>
<thead>
<tr>
<th>Category</th>
<th>Term used to describe approach</th>
<th>Author, Year and Reference</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBDRR initiative was created and managed by the community</td>
<td>Citizen contributions</td>
<td>Forrest, Trell, and Wolter, 2020 [87]</td>
<td>Netherlands</td>
</tr>
<tr>
<td></td>
<td>Community-based/local knowledge</td>
<td>Šakić Trogšić et al., 2018 [88]</td>
<td>Malawi</td>
</tr>
<tr>
<td></td>
<td>Community-based flood risk management</td>
<td>Šakić Trogšić et al., 2019, [60]</td>
<td>Malawi</td>
</tr>
<tr>
<td></td>
<td>Community-based approach</td>
<td>Shariff and Hamidi, 2019 [89]</td>
<td>Malaysia</td>
</tr>
<tr>
<td></td>
<td>citizen-based knowledge</td>
<td>Ramsey et al., 2019 [90]</td>
<td>Puerto Rico (USA)</td>
</tr>
<tr>
<td></td>
<td>Organic community-based disaster risk management</td>
<td>Tanswattana, 2018 [91]</td>
<td>Thailand</td>
</tr>
<tr>
<td></td>
<td>Co-production in flood risk governance</td>
<td>Mees et al., 2018 [92]</td>
<td>United Kingdom, Belgium, France, Netherlands and Poland</td>
</tr>
<tr>
<td></td>
<td>Co-production</td>
<td>Schaar and Hanonou, 2017 [61]</td>
<td>Senegal</td>
</tr>
<tr>
<td>CBDRR initiative was created by external agents and is managed primarily by the community</td>
<td>Community-Based Collaborative research</td>
<td>Goodrich et al., 2020 [19]</td>
<td>Mexico</td>
</tr>
<tr>
<td></td>
<td>Citizen Science</td>
<td>Newman et al. 2020, [93]</td>
<td>USA</td>
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<tr>
<td></td>
<td>Participatory sketch mapping</td>
<td>Brandt et al., 2019 [3]</td>
<td>Belize</td>
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<tr>
<td></td>
<td>Records collected by the affected community</td>
<td>Re, Kazimierski, and Badano, 2019 [57]</td>
<td>Argentina</td>
</tr>
<tr>
<td></td>
<td>Community-based scenario planning</td>
<td>Buckman, Arqueiro de Alarcon, and Maigret, 2019 [94]</td>
<td>USA</td>
</tr>
<tr>
<td></td>
<td>Citizen Science</td>
<td>Cheung and Feldman, 2019 [95]</td>
<td>USA and Mexico</td>
</tr>
<tr>
<td></td>
<td>Crowdsourcing</td>
<td>Gebrmedhin et al., 2020 [17]</td>
<td>Tanzania</td>
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<tr>
<td></td>
<td>Citizen science</td>
<td>Glas et al., 2020 [18]</td>
<td>Haiti</td>
</tr>
<tr>
<td></td>
<td>Community Mapping</td>
<td>Peterson, 2020 [96]</td>
<td>Tanzania</td>
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<tr>
<td></td>
<td>Participative pre-flood risk reduction</td>
<td>O’Grady et al., 2019 [97]</td>
<td>United Kingdom</td>
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<tr>
<td></td>
<td>Citizen Science</td>
<td>Lofus et al., 2019 [98]</td>
<td>USA</td>
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<tr>
<td></td>
<td>Crowdsourced</td>
<td>Villani et al., 2019 [99]</td>
<td>Italy</td>
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<td></td>
<td>Volunteered geographic information</td>
<td>Rollason et al., 2018 [100]</td>
<td>United Kingdom</td>
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<tr>
<td></td>
<td>Crowdsourced data</td>
<td>Panteras and Cervone, 2018 [101]</td>
<td>USA</td>
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<tr>
<td></td>
<td>Crowdsourced observations</td>
<td>Mazzoleni et al., 2018 [46]</td>
<td>Italy</td>
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<tr>
<td></td>
<td>Citizen science</td>
<td>Fava et al., 2018 [102]</td>
<td>Brazil</td>
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<tr>
<td></td>
<td>Crowdsourcing</td>
<td>Frigerio et al., 2018 [16]</td>
<td>Denmark</td>
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<td></td>
<td>Stakeholders’ knowledge</td>
<td>Hazarika et al., 2018 [26]</td>
<td>India</td>
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<td></td>
<td>Social perception</td>
<td>Adomah Bempah and Olav Øyhus, 2017 [96]</td>
<td>Ghana</td>
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<tr>
<td></td>
<td>Community-based flood risk assessment</td>
<td>Li, Xu, and Wen, 2016 [42]</td>
<td>China</td>
</tr>
<tr>
<td></td>
<td>Community-based disaster risk index</td>
<td>Komi, Amisigo, and Diekkrüger, 2016 [36]</td>
<td>Togo</td>
</tr>
<tr>
<td></td>
<td>Crowdsourced data / citizen science</td>
<td>Le Guz et al., 2016 [40]</td>
<td>Argentina, France and New Zealand</td>
</tr>
<tr>
<td></td>
<td>Community-based flood damage assessment</td>
<td>Perera et al., 2015 [103]</td>
<td>Nepal</td>
</tr>
<tr>
<td>CBDRR initiative was created by external agents and is exclusively used by external agents</td>
<td>Crowdsourced social media photos</td>
<td>Pereira et al., 2020 [53]</td>
<td>Undefined</td>
</tr>
<tr>
<td></td>
<td>Social media</td>
<td>Kankanamge et al., 2020 [32]</td>
<td>Australia</td>
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<tr>
<td></td>
<td>Crowdsourced Data</td>
<td>Puttinaovart and Horkaew, 2020 [104]</td>
<td>Thailand</td>
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<tr>
<td></td>
<td>Crowdsourced</td>
<td>Mobley et al., 2019 [105]</td>
<td>USA</td>
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<tr>
<td></td>
<td>Volunteered Geographic Information (VGI)</td>
<td>Feng and Sester, 2018 [106]</td>
<td>France, Germany and United Kingdom</td>
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<tr>
<td></td>
<td>Social sensing/social media/crowdsourcing</td>
<td>Arthur et al., 2018 [107]</td>
<td>United Kingdom</td>
</tr>
<tr>
<td></td>
<td>Social media and crowdsourcing data</td>
<td>Wang, 2018 [108]</td>
<td>USA</td>
</tr>
<tr>
<td></td>
<td>Citizen-Reported Flash Flood Data</td>
<td>Smith and Rodriguez, 2017 [67]</td>
<td>USA</td>
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</tbody>
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using OpenStreetMap that sought to improve local databases by engaging community members in local participatory mapping processes [1].

Among the 40 articles, the term “crowdsourcing” and variants were used in 14 articles that intended to involve community members primarily in the condition of data gatherers. These articles have all applied methods based on the use of data from social media or open internet-based datasets. Conversely, the concept of “community-based” has more frequently been used to describe approaches with varying degrees of community input in data-collection and/or involvement in the research design or in later stages of decision-making. The term “community-based” and similar variants have appeared in 10 out of the 40 articles reviewed. The goals and expectations regarding the data validity and quality are also vastly different between these two main groups.

In general, most articles following the probabilistic risk approach still demonstrate mistrust towards crowdsourced data-collection methods. These articles tend to describe them as generally “asynchronous and inaccurate” yet still useful as they “can still complement traditional networks formed by few accurate, static sensors and improve the accuracy of flood forecasts”[47]. While this crowdsourced data is still perceived as limited in terms of validity, its application has also been seen as able to “fulfill other requirements, such as abundance and spatial distribution” particularly when the assessment method incorporates data produced in social media [12]. These publications have demonstrated a different perspective in relation to other case studies that describe CBDRR initiatives created by community members.

The term “community based” has been used in various publications to describe varying degrees of community participation. The articles that demonstrated in-depth involvement of communities in registering flood perceptions and developing long-term plans for preparing and responding to floods often used the term “community-based” to describe the assessment process. One study in India used an anthropologically oriented process for identifying hazard and vulnerability indicators that combines individual and group interviews with floodplain inhabitants, field observations and governmental data [26]. Conversely, several studies have used the terms “community-based” or “citizen science” without clearly demonstrating if the community was involved in the assessment process in any substantial way. These included some works conducted in China [42], Haiti [18] and Togo [36] in which the extent of community participation of community-members was unclear.

In a study conducted in a large flood-prone urbanised area in Togo, the authors referred to community participation through indexes used as a method for assessing floods [36]. Even though the study used the term “community based” it did not provide evidence that the approach significantly involved community-members except for assessing the intensity of the previously experienced floods in the area. This criterion was assessed using one questionnaire per community that engaged “only knowledgeable people (members of the local development committee, formal community leader, teacher, etc)” [36]. Similarly, a study in Haiti claimed to demonstrate the potential of citizen science applications but provided limited evidence of significant community involvement. The term citizen science in this article was used to refer to a questionnaire administered to communities to quantify damage perception from previous floods [18].

Based on these findings, the next section discusses a case study of community-based flood monitoring conducted within the Revitalising Informal Settlements and their Environments (RISE) program [4]. In brief, RISE is a public health project investigating the effects of the implementation of nature-based infrastructure in informal settlements. While RISE is not a flood risk reduction program, assessing flood risks became an important component of the research agenda since many of the participating settlements are located in flood-prone areas [56].

4. Case study: flood monitoring within the RISE program

Being a long-term action-research program, the practices developed within RISE and the involvement of the community with the program also form part of the research agenda. Among the program’s activities, the community-based flood-monitoring project intended to document floods over time to support decision-making and provide designers with flood evidence for validating models and informing infrastructure planning.

The flood-monitoring project developed within RISE commenced in December 2018 and was conducted in seven settlements in Suva (Fiji) and in six settlements in Makassar (Indonesia). The settlements were selected based on: (i) previous studies [31,70], (ii) the anecdotal descriptions of past floods, and (iii) site visits to assess the local hydrological conditions.

The project was established following a citizen science approach since the participating community-members had no previous training in flood mapping, yet actively contributed to the development of a database on water-level documentation to support infrastructure planning. All of the participants lived in the communities and were familiar with the floods experienced in the sites. There were no specific requirements for participating, but the organising team demonstrated interest in working with a diverse group of volunteers in terms of ages and gender. The final selection of participants was conducted by the RISE fieldworkers that had more familiarity with the community and by local community leaders. As such, the ongoing relationship with the communities meant that the flood monitoring program within RISE did not face the usual challenge of finding volunteers, which has been reported as a main concern in other similar projects [10].

A gauge and a crest level indicator were installed in close proximity to their homes in a position expected to register significant water level fluctuations according to anecdotal flood descriptions shared by the community (as shown in Fig. 1). The participants were instructed to use their personal smart phones to send photos of the flood gauges daily in order to keep a record of the water levels throughout the whole rainy season. During flood events, the volunteers were asked to photograph the gauge periodically at two hour intervals. The photos were shared in a common messaging group where all volunteers were able to communicate and comment on each other’s photos. This connection between volunteers played a significant role in creating an identity for the monitoring program and motivating participation in the community. This is one of the long-term challenges indicated in the literature, with respect to this kind of program [41]. Once received, the images were downloaded into a database and interpreted individually.

RISE fieldworkers played an instrumental role in the program by selecting the volunteers, installing the gauges and engaging the community in the continuous monitoring activity. The training consisted of a simple demonstrative session in which the staff member took a photo of the gauge from a reasonable distance and explained the rationale and intentions with the activity. This is an important aspect since published works describing citizen science projects do not always explain how training was conducted or how errors from volunteer participation were addressed [10]. The work of monitoring water levels was done voluntarily and the only compensation offered was a monthly reimbursement to cover the access to the internet for sharing the images.

Over the 8 months of monitoring, across two rainy seasons (end of December 2018 to end of April 2019 and end of December 2019 to April 2020), more than 5000 photos in total were received from community-members in Indonesia and Fiji. The photos allowed for a comprehensive documentation of water levels in different settlements across the same catchment and, therefore, provided useful evidence of flood risks in the area. As an example, Fig. 2 shows water levels registered in the month of January 2019 in four different settlements in the Tallo river watershed area.

While the flood references collected through the monitoring project were not sufficient to fully characterise the hydrology of the region, the water-levels registered in Fig. 2 were used within RISE to calibrate small-scale bucket flood models. These references were compared to rainfall data collected from an external dataset [28] and used as a preliminary indication of the local flood risk profile. Similar to approaches discussed by other authors, the monitoring was able to determine with significant
The citizen science flood-monitoring project conducted in RISE was able to gather evidence that the communities of Alla Alla, Kampung Baru, Batua, Borong Raya, Co’de and Barawaja are significantly affected by floods. In particular, photos of the gauges in the settlements of Kampung Baru, Batua and Alla Alla documented the severe flooding experienced by community-members in 2019. This flood blocked the access to the settlements and reached the ground floor of several houses causing considerable damage to the local residents. In Fig. 2, one of the data points represents a water level of 300 cm registered in Kampung Baru evidencing this event.

This point indicates the highest water level registered throughout the whole period and was assessed using the crest meter, which registered the flood peak during a day in which the community was evacuated by authorities following extreme flood levels. For this particular case, it was not possible to determine the precise moment of the flood peak.

A more accessible version of these graphs was shared with the contributing volunteers at the end of each month. This simple report with graphs illustrated the water levels documented in each settlement throughout the period and served as a reminder of flood intensity and duration. Evidence suggests that the results of the flood monitoring were highly valued by community-members that shared the findings of...
the program widely and described feeling proud for having contributed to this initiative.

4.1. Findings from the case study

This section investigates the role played by community-members within RISE program’s flood monitoring project. It also discusses whether the community-based flood monitoring project had any additional social and cultural benefits to the community in terms of flood risk reduction. This investigation is relevant to position the project in relation to the wider literature discussed earlier in this article.

The analysis of the social and cultural benefits of the community-based flood monitoring in RISE was conducted based on interviews with RISE staff members and open-ended questionnaires administered to participating community-members. Being part of an action-research project [109], all of the investigations here described followed Monash University Human Ethics Research Committee’s guidelines and were submitted and approved by the university before commencement.

The questionnaires revealed that in addition to providing evidence to validate flood models, the monitoring activity had other beneficial effects for the community. For example, community-members that were directly involved in the project declared having a positive experience when sharing flood information with other volunteers living in neighbouring communities. The collaborative platform initially planned to share photos was also used by the participants to share personal perceptions of floods as well as other useful information such as weather forecasts. These situations indicate that the citizen science approach was successful at creating a collaborative space for knowledge sharing. Evidence from interviews also suggest that the group of collaborators shared the results of the monitoring process with others, further expanding the reach of the project and support local knowledge creation.

From a political perspective, some of the participants also declared having interest in the results of the project because they provide them with validated evidence of floods in the region. One of the interviewed community leaders indicated that the citizen science project offered them an accessible and clear documentation of flood levels has the potential to support local advocacy for infrastructural improvements in the settlements. She declared: “It is very good that RISE is looking at the floods in our community. I would like to get a good document at the end that I can take to the Bappeda [city planning agency] to show them the floods we have here. This is going to prove that we need help from the government.” Resident from Kampung Baru

This quote reveals that the flood monitoring initiative can, beyond supporting data-collection, play an important social and political role. Similarly, several other participants have also described a feeling of accomplishment and pride for being part of the project. Some insisted that they would be happy to participate again in the future because they think that the monitoring can help in the design of future infrastructure in the region. This suggests that the documentation process, which was initially intended to provide evidence for an external institution, has gradually been understood as a practice also aligned with the local interests. The community mobilisation and bonding resulting from the project has been interpreted as an indication that this project might lead to future initiatives that will further support local interests and facilitate the creation of local knowledge repositories. These results are similar to the findings of other studies that described community-based projects developed in other parts of Indonesia [45,52].

While the initial objective in RISE was to collect data to support external decision-making processes, there is clear evidence that the community has been directly benefitted by the citizen science project. These findings show that the experiences from the RISE program are consistent with the other cases documented in the recent literature covering community-based approaches applied to address flood risks all over the world (Le [40]). In the following section, I revisit these findings and the lessons from the case studies reviewed to recommend future fields of study.

5. Conclusions: community-based approaches and the promise of a “people-centred approach” to flood risk

The literature review revealed that approaches to flood risk assessment commonly described as “citizen science” and “crowdsourced data” have gained currency as tools to support flood risk assessment over the last decade [72]. While technical and logistical limitations in the application of citizen science still exist [13], the past few years have witnessed considerable growth in the publications that acknowledge the use of participatory approaches within the realm of flood modelling [2]. Similarly, aligned with the literature on the field, several publications have indicated that community-based projects can foster the involvement of various stakeholders in discussions that previously were only held by specialists [48]. However, while most publications suggested that community-based projects have significant social and cultural benefits, few articles provided evidence that communities were effectively participating in the definition and implementation of the initiatives.

Aligned with other publications [55], the case study discussed in this article suggests that the RISE program’s citizen science project had significant benefits for the community. As observed in the case study, several reviewed projects suggest that citizen science approaches can contribute to improve local scientific literacy, strengthen local networks, facilitate the participation of local community members in decision-making and enhance the quality of management practices due to the larger scale monitoring capacity [9]. As such, the conclusions of most reviewed articles indicate that citizen science and community-based risk reduction projects have the potential to complement the methods traditionally applied to reduce flood risks all over the world [82].

The review also showed that citizen science and community-based projects have been increasingly popular in the flood-related literature. Authors with a more probabilistic view of risks framed these projects as a way to cover the limitations of traditional satellite imagery and sensor-based models [30] as well as to reduce costs [18]. Citizen science initiatives were also recognised for enhancing the spatial distribution of existing flood modelling methods [12]. Several studies also revealed that interdisciplinary negotiations remain challenging for reconciling probabilistic and social approaches towards risk.

The importance of considering social and cultural aspects in the creation of multi-dimensional, multi-stakeholder plans has been evidenced by some of the publications. These publications documented ethnographically oriented processes and generated unique insights into the perceptions of floods in particular contexts (Šakić [26,60]). However, to answer if these projects are offering a more people-centred approach to disaster risk reduction, it is important to analyse to what extent communities were involved in the conceptualisation of the projects as well as who is currently benefiting from the results of the studies.

The findings from the review show that community-led initiatives are uncommon in the peer-reviewed literature as most articles describe monitoring projects started not by communities but by the authors themselves. A study in Argentina, for instance, acknowledges that the idea for the community-based framework was inspired by flood records collected by local community leaders but conducted by the authors [57]. The project initiated by the community in this case was then transformed into a flood risk assessment and mitigation framework that incorporated the community-based records into simulations developed and analysed by the authors.

The review also reinforces some expected findings about citizen science projects. The studies reveal that the collection of flood data through citizen science methods has been used in different contexts for different reasons including to improve long-term hydrological modelling [44,69] and to facilitate the provision of emergency services during flooding [15,71]. Responding to the challenge of creating a more people-centred approach to flood risks, the lessons from the case study confirm the potential of community-based strategies as an auxiliary long-term approaches to support disaster risk reduction in the Global South. However, the literature review on community-based flood monitoring approaches reveal that most reported projects do not engage with participants in the early stages of
the process as much as intended. This is not suprising as the literature on citizen science applied to environmental monitoring has been discussing the same phenomenon for over two decades [8,10,35]. This raises the concern that most projects engage with citizens primarily in the condition of data-collectors to compile flood-related data for governmental or specialist-cantered decision-making. While not necessarily problematic, this reveals that flood risk assessment is still predominantly a centralised activity and not a multi-stakeholder process as recommended by the SFDRR [77]. Could future approaches open opportunities for more transparent and collaborative approaches where communities are not only involved as sensors? Additional research is needed to answer this question, but this literature review suggested new research directions for the involvement of citizens as interpreters, analysis as well as decision-makers.

The analysis of the RISE program’s citizen science framework suggests that this specific project is similar to others found in the literature that seek to involve communities in the practice of flood monitoring. In these projects the action of monitoring is understood as the act of quantifying the effects of disruptions and informing whenever a system is behaving differently from the desired state [41]. As such, the project counts on community members to behave as sensors that collect data, but also open possibilities for the participants to share their perceptions and interpretation of the flooding. This example points to a unique potential of citizen science projects based on the notion of community-based monitoring. This kind of project, through which community-members and other stakeholders collaborate to document and respond to environmental issues of common concern or interest [81], indicates a promising opportunity for citizen science methods to gain space within the disaster risk reduction toolset.

Credit author statement

I have developed this work during my doctoral studies with minimal input from my supervisors in the conceptualisation and development of the text. My supervisors supported me with funding for the research, but all other contributions to this work are mine.

Declaration of Competing Interest

None.

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References


