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Current flood risk management practices in Ghana: Gaps and opportunities for improving resilience

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Abstract

This article evaluates the current gaps and describes opportunities for improving flood risk management (FRM) in Ghana, West Africa. A mixed-method participatory approach comprising questionnaires, workshops, interviews with key stakeholders, and a systematic literature review were employed. Existing problems, discourses, FRM practices, and opportunities to enhance flood resilience were identified. They provided the basis for outlining potential research directions into ways of tracking these challenges. The results show how different actors perceive FRM in Ghana. The stakeholders interviewed have different, and even contradictory perceptions of the effectiveness of FRM, which are embedded in their diverse storylines. The findings show that Ghana's FRM is still reactive rather than preventive and that research in the field of quantitative hazard and risk assessment is still rudimentary. FRM policies and flood early warning systems (FEWS) are in place, but efforts should be directed towards their implementation and monitoring, investigation of social and technical capacity aspects, and enhancement of institutions' mandates, and coordination. Moreover, the findings illustrate that FRM is moving toward a more constructive engagement of citizens and stakeholders. However, policies and action plans need to consider more inclusive community participation in planning and management to effectively improve their resilience and develop sustainable solutions.

KEYWORDS

disaster risk, flood risk management, Ghana, governance, resilience, stakeholders

1 | INTRODUCTION

Ghana is one of the countries most prone to floods in West Africa (Aggrey, 2015; Amoateng, Finlayson, Howard, & Wilson, 2018; World Bank, 2011) with devastating

Adrian Almoradie and Mariana Madruga de Brito contributed equally to this study.

effects, especially for the urban poor (Okyere, Yacouba, & Gilgenbach, 2013). In 2017, Ghana experienced extreme floods that affected about 1 million people (Adegoke et al., 2019; IFRC, 2017). In 2018, floods caused by high-intensity rainfall combined with water releases from the Bagre Dam in Burkina Faso affected 100,000 people and destroyed 196 km^2 of farmland (FLOODLIST, 2018). Besides the annual occurrence of major floods, Ghana also experiences cascading disasters triggered by floods, which disrupt critical infrastructure. For example, in 2015, Accra experienced a cascade disaster of floods and fire, driven by both natural and human factors. Due to a cigarette dropped into flood water that had fuel on the surface, a state-owned gasoline station exploded, claiming the lives of 152 people and damaging properties worth millions of dollars (Quarshie et al., 2018; Yankson, Owusu, Owusu, Boakye-Danquah, & Tetteh, 2017).

With flood events expected to increase in frequency and severity in Ghana due to climate change (IPCC, 2012; World Bank, 2011), flood risk management (FRM) regimes and sustainable adaptation approaches are urgently needed. To tackle this, the Ghanaian government has established several policies to reduce flood impacts. These include primarily the National Water Policy (Government of Ghana, 2007) which creates measures to mitigate floods by adopting flood early warnings, by ensuring that mitigation strategies are implemented in consultation with the affected communities and by enforcing buffer zone laws. As defined by Ghana's National Water Policy (Government of Ghana, 2007), buffer zone laws aim to prevent people from settling within a certain distance from river banks. Another important policy is the Blue Agenda (Addo & Danso, 2017), which addresses flooding and its related threats by focusing on public education and the enforcement of building regulations.

Despite the existence of several institutional and non-institutional FRM programmes (e.g., Asare-Kyei, Forkuor, & Venus, 2015), the recurrence of flood disasters contradicts the effectiveness of the existing FRM regimes. This discrepancy has been pointed out in previous studies (e.g., Ahadzie & Proverbs, 2011; Kufour, Meyir, & Clifford, 2018; Thiemig, de Roo, & Gadain, 2011; World Bank, 2011). In this regard, Addo and Danso (2017) highlighted that a series of socio-political factors have made it difficult to effectively implement existing laws and policies for FRM. Moreover, both city authorities and exposed communities commonly embrace a reactive approach, focused on demolitions, forced evictions, seeking temporary refuges, and adopting palliative measures (Afriyie, Ganle, & Santos, 2018; Amoako, Cobbinah, & Mensah Darkwah, 2019; Danso & Addo, 2017; Tengan & Aigbavboa, 2016). These factors draw attention to the need to find and introduce sustainable solutions to managing flood risk in Ghana.

The dichotomy between the existing FRM infrastructure and the reality of recurring destructive floods is, therefore, the main rationale for this study. Here, we aim to contribute to the understanding of the effectiveness of the FRM regimes in Ghana and to offer a context for exploring options to enhance resilience and achieve sustainable solutions. To provide insights into the factors that contribute to the severity of flood impacts in Ghana and analyse current discourses and FRM practices, an inter-and trans-disciplinary approach was employed. For this purpose, questionnaires and interviews with key experts and stakeholders as well as a systematic literature review were conducted.

This research was carried out in the definition project "Participatory assessment of flood related disaster prevention and development of an adapted coping system in Ghana (PARADeS)" which aims to explore and identify the current status, gaps, weaknesses, and challenges of Ghana's FRM and strategy on a national level.

The subsequent sections present the methods and their implementation. This is followed by the findings and discussion of the literature review and the participatory approach employed. Finally, we discuss ways to move forward and present some concluding remarks regarding Ghana's FRM practices.

2 | PARTICIPATORY METHODS FOR THE ASSESSMENT OF FRM PRACTICES IN GHANA

2.1 | Systematic literature review

In the first step, a quantitative literature review was undertaken to analyse peer-reviewed articles that address FRM in Ghana. Both Web of Science and Science Direct databases were systematically searched following the protocol outlined by Pickering and Byrne (2014). To find eligible articles, the search strings ("flood*" OR "inundation*)" AND "Ghana*" were used in the titles, abstracts, and keywords. Given that we aim to identify current issues, the search was restricted to articles written in English and that were published between January 2009 and February 2019.

These queries yielded 165 references which were screened to identify those focused on FRM. After screening the respective abstracts, 110 articles were excluded as flooding was not their main focus. Additionally, two articles were removed as they were not accessible. Hence, the final number of studies was 53. These were then classified according to their publication year, journal, type of FRM problem, case study area, the scale of the analysis, whether it was or was not carried out in a participatory

process, and the participatory methods applied. The analysis of these scientific articles is presented in Section 3.

2.2 | Stakeholder analysis

As with any participatory study, the identification of key stakeholders who are knowledgeable of the current situation with respect to Ghana's FRM is crucial (de Brito, Evers, & Almoradie, 2018; Evers, Jonoski, Almoradie, & Lange, 2016). In this subsection, we present the method used to identify them. This was achieved using a non-probability sampling technique called snowball sampling (Wright & Stein, 2005). During this process, the stakeholders initially sampled (i.e., starting seeds) indicated other specialists in the field, who in turn pointed to other prospective participants and so on (de Brito, Evers, & Höllermann, 2017). On this basis, 64 actors were identified. Of these, 51 stakeholders for whom contact information was available were approached by email to ask whether they would be willing to collaborate in the project and attend the meetings and surveys. A total of 33 stakeholders (64.70%) replied. Figure 1 depicts a sociogram organised by the degree of centrality (Musiał, Kazienko, & Bródka, 2009), in which the stakeholders with more connections are located in the center of the graph. In two cases, they correspond to the starting seeds (i.e., the stakeholders who were first contacted).

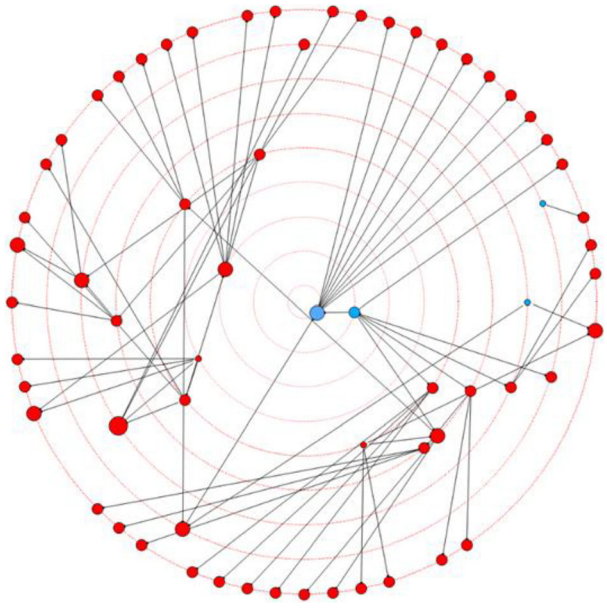

FIGURE 1 Social network diagram depicting the linkages between the identified stakeholders. Each node represents an actor. The circles collect all experts with the same degree of centrality. The blue dots denote the stakeholders who were first contacted

2.3 | Stakeholder online survey

To obtain the first insights into the current FRM situation and to provide information for the workshop, a web-based questionnaire was prepared. The survey consisted of 10 questions, which aimed at identifying existing gaps and analysing the effectiveness of existing FRM structural and non-structural measures and programmes. Survey questions were a mixture of open-ended, multiple responses, and Likert-scale questions related to key elements of risk perception; understanding of flood governance structures; and main vulnerabilities. A total of 33 stakeholders (64.70% of those invited) participated in the online survey. The results and analysis of the online survey are presented in Section 4.

2.4 | Stakeholders' workshop

A one-day workshop with 29 participants (18 stakeholders and 11 Ghanaian PARADeS project partners) identified through snowball sampling (Figure 1) was organised in Accra. The goal was to identify the current status, weaknesses, and challenges of the FRM in Ghana on a national level. At the beginning of the workshop, a participatory mapping exercise was conducted and participants were requested to pinpoint on a map areas prone to coastal, urban and river floods, and areas with high social vulnerability.

The participants then worked together to further explore the gaps identified in the online survey (Session 2.3) by using the problem tree method. This tool assists in examining an existing situation by identifying major problems and their causal relationships. The output is a graphical arrangement of problems differentiated according to "causes" and "effects," joined by a core problem (Baldwin, Loveday, Li, Murray, & Yu, 2018). Participants were split into five heterogeneous teams to ensure a balance of expertise and a holistic perspective. The core problem given was FRM in Ghana. However, each group created a separate problem tree and had the freedom to explore key issues they thought were relevant. This made it possible to open up the debate for distinct core issues.

The last workshop session comprised an unstructured group discussion about coping strategies for FRM and risk governance and policy. The participants were divided into two groups, and each was given one topic for discussion: (a) concept and practice of the national and local flood risk governance and policy; and (b) evaluation of existing FRM coping and adaptation strategies. These topics were freely discussed by the participants. The moderator took a neutral approach, encouraging the

discussion of different opinions, but evaluated neither the arguments nor the described effectiveness of existing strategies and policies. At the end of the session, each group presented the results of their team to all the stakeholders in a plenary discussion. The results and analysis of the workshop are presented in Section 4.

2.5 | Key institutions interviews

Institutional surveys (Appendix A) were conducted with 20 key organisations that play a crucial role in FRM in Ghana. These include, for example, Water Resources Commission (WRC), Hydrological Service Department, Ghana Meteorological Agency (GMet), Water Research Institute (WRI), National Disaster Management Organisation (NADMO), Land Use and Spatial Planning Authority (LUSPA), Ministry of Sanitation and Water Resources, Red Cross, National Ambulance, National Fire Service and Armed Forces. An expert sampling technique was used in identifying these organisations, categorising them based on their mandates and functions such as governance and implementation, security agencies and research and academia. The persons interviewed differed from those who participated in the workshop. However, their institutions sometimes overlapped.

The institutional surveys allowed us to capture information, knowledge, and perception that were not shared during the stakeholders' workshop. The interviews focused on the following aspects: (a) data, modelling, and risk assessment and analysis; (b) development of scenarios and prevention and adaptation strategies; (c) flood risk governance; (d) analysis of human-floods dynamics and stakeholder participation; (e) technical tools and mechanism integration for improved disaster risk management; (f) capacity development; and (g) sustainable implementation of risk policy, strategies, and mechanisms. Apart from this, stakeholders were interviewed on their level of knowledge of the topics of flood preparedness, early warning, response, and recovery using a 4-point likert scale (very poor to very good). The surveys lasted on average 45 min, depending on the respondent's knowledge, and level of engagement. The results and analysis of the interviews are presented in Section 4.

3 | FINDINGS OF THE STATE-OF-THE-ART REVIEW OF FRM STUDIES IN GHANA

This section provides an overview of the FRM scientific outputs produced during the last decade in Ghana. A total of 53 articles published between 2009 and 2019 in 35 different journals were systematically reviewed. Appendix B summarises the main features of these studies.

3.1 | Trends by year of publication and research focus

The number of FRM publications increased in the course of the last decade (Figure 2a) and the majority of studies were published between 2017 and 2018 (52.83%, $n = 28$). A reason for this increase may be a reflection of a growing awareness of flood risk prevention and reduction policies in West Africa (Adegoke, Sylla, Bossa, Ogunjobi, & Adounkpe, 2019). Alternatively, this may be due to recent investments in climate and extreme events research (e.g., creation of WASCAL in 2012 and projects such as Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa: an integrated approach—CECAR-AFRICA). To correctly measure the interest in flood research in Ghana, an increase in relative terms was calculated. A normalisation was made according to the number of all papers published about Ghana in the Web of Science database. Figure 2b shows that the increase in flood publications in Ghana is greater than the increase in publications about Ghana. This confirms the hypothesis that the interest in floods has been growing considerably, especially since 2015.

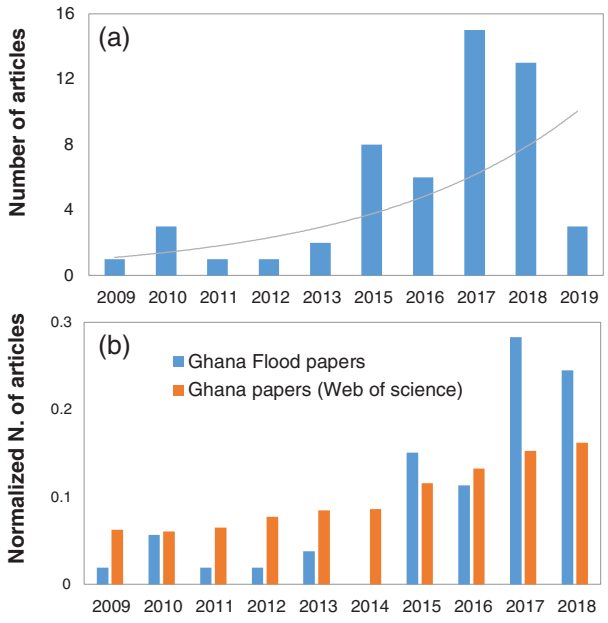

FIGURE 2 (a) Number of Ghana FRM articles published over the period 2009–February 2019 ($n = 53$). (b) Normalised number of papers about floods in Ghana (in blue) and normalised number of papers written about Ghana based on data from Web of Science

Most of the articles (28 out of 53, 52.83%) investigated more than one FRM problem (e.g., some articles assessed both flood vulnerability and risk). Therefore, the number of items discussed is 93. Among the investigated topics, the most prominent theme was the analysis of flood adaptation strategies (15.05%, $n = 14$), closely followed by risk perception and vulnerability studies (both 13.98%, $n = 13$; Figure 3). The interest in adaptation studies may be explained by the use of traditional and knowledge-based systems and practices by local communities. According to Ngwese, Saito, Sato, Boafo, and Jasaw (2018) and Frick-Trzebitzky, Baghel, and Bruns (2017), the lack of science-based tools and systems for FRM in Ghana instigates the development of creative strategies for dealing with floods. Nevertheless, some studies pointed out that the majority of the flood victims still opt for reactive and reactionary coping and adaptation strategies rather than preventive ones, which are usually costly and sometimes ineffective (Amoateng et al., 2018; Danso & Addo, 2017). Amoako et al. (2019) further described that FRM in Ghana has been largely limited because of weak urban planning. According to the authors, responses are characterised by reactionary interventions in the form of the demolition of buildings, forced evictions, construction and desilting of storm drains, and distribution of relief items. With regard to the participation of stakeholders, the literature review revealed that most of the studies (77.33%, $n = 41$) consider some sort of participation. This aspect will be discussed in detail in Section 3.3.

The high number of vulnerability and risk perception studies in contrast to hazard assessments contradicts the findings of other authors (de Brito et al., 2018; Jongman & Aerts, 2015; Koks, Jongman, Husby, & Botzen, 2015; Sorg et al., 2018), who point out that hazard studies are more frequent than vulnerability assessments. Based on these findings, it becomes clear that one of the main gaps for FRM in Ghana relates to the assessment of risk, as hazard and risk studies are still rare. This can be explained by the lack of hydrological, rainfall, and land-use data, which is mentioned as an issue in several studies (Kleemann, Celio, & Fürst, 2017; Osman, Nyarko, & Mariwah, 2016). In this regard, qualitative tools to investigate peoples' risk perception and adaptation strategies are preferred given that they are easily accessible in data-scarce environments.

Despite the recurrence of floods that trigger cascading and compound disasters (Yankson et al., 2017), only two studies tackled this issue (Quarshie et al., 2018; Songsore, 2017). For instance, Songsore (2017) investigated how the risk of cholera outbreaks increased due to floods in Accra. Notwithstanding this initiative, the health risks posed by floods in post-disaster settings not only in Ghana but also worldwide are still poorly understood. This information is critical to inform preparedness strategies (Cutter, 2018; Suk, Vaughan, & Cook, 2019) and is recognised as a priority in the Sendai Framework for Disaster Risk and Reduction (DRR; UNISDR, 2015).

3.2 | Case study area and spatial scale

The reviewed articles focus mostly on local case studies (Figure 4), especially in neighbourhoods located in Accra (39.62%, $n = 21$; e.g., Agbogbloshie and Glefe communities), Kumasi (13.21%, $n = 7$) and in the Volta Delta (7.55%, $n = 4$). None were developed at the national scale. This highlights the need for nationwide studies as these can provide an overview of the current vulnerability and risk, and allow for the drawing of comparisons and generalisations. A detailed list of the case study areas

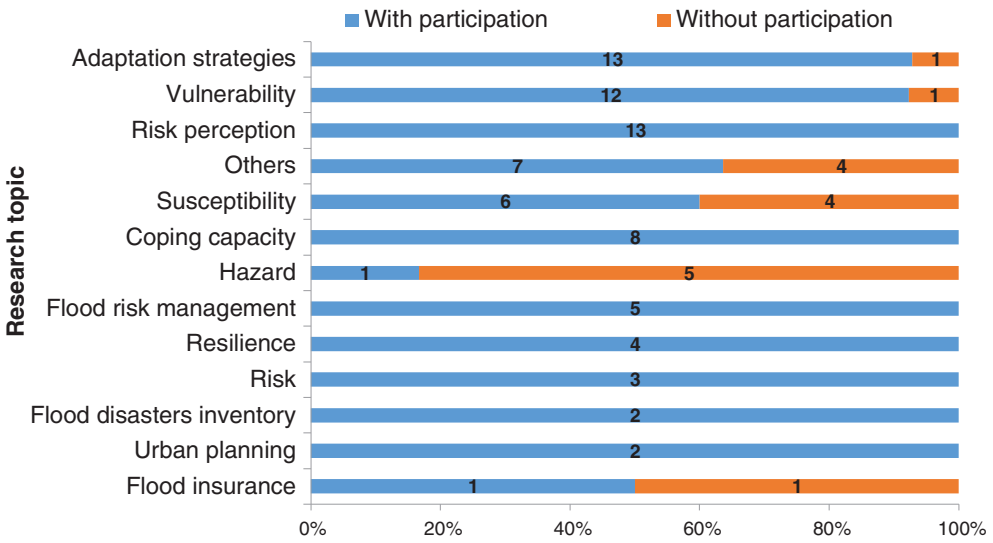

FIGURE 3 Distribution of research applications according to FRM topic and with/without participation ($n = 93$). The total number of articles per topic is arranged in increasing order and is highlighted in bold

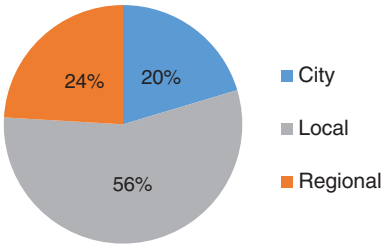

FIGURE 4 Spatial scale of the reviewed studies ($n = 54$)

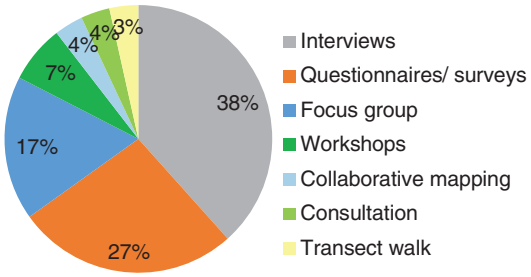

FIGURE 5 Participatory methods used to incorporate multiple stakeholders' views on the reviewed articles. Only methods that were mentioned twice were included. The $n = 86$ as some articles mention more than one participatory method

included in the reviewed studies is provided in Appendix B.

In Accra, riverine and urban floods occur annually and have pronounced impacts in informal settlements (Amoako et al., 2019; Amoako & Inkoom, 2018; Douglas et al., 2008). Floods are triggered by seasonal rainfall combined with poor drainage, dumping of waste into waterways and low elevation of settlements (Amoako & Boamah, 2015). Similar to Accra, the impacts of riverine and urban floods in Kumasi are substantially increased by the lack of drainage or by insufficient drainage and by the relatively large proportions of informal settlements which are haphazardly positioned (Campion & Venzke, 2013). In the Volta Delta, coastal erosion and flooding are estimated to have destroyed about 5,000 houses since the 1960s, forcing migration within and out of the Delta (Addo, Jayson-Quashigah, Codjoe, & Martey, 2018; Karley, 2009). The construction of the Akosombo dam, overharvesting of mangroves, and sand mining have been identified as the major causes of flooding in the Delta (Addo et al., 2018; Boateng, 2012; Codjoe, Nyamedor, Sward, & Dovie, 2017).

Surprisingly, flood-prone areas (Bempah & Øyhus, 2017) such as the White and Black Volta River Basin in the Upper East Region have rarely been studied. This may be because floods in these areas are caused by spillage from the Bagre dam in Burkina Faso (Armah, Yawson, Yengoh, Odoi, & Afrifa, 2010; Asare-Kyei, Renaud, Kloos, Walz, & Rhyner, 2017; FLOODLIST, 2018), which makes the modelling and development of adaptation measures more complex as it requires transboundary cooperation and negotiation. In addition to the high hazard frequency, households in this region have the highest social vulnerability and lowest adaptive capacity (Antwi-Agyei, Dougill, Stringer, & Codjoe, 2018; Antwi-Agyei, Fraser, Dougill, Stringer, & Simelton, 2012; Tambo, 2016).

3.3 | Participation of stakeholders and citizens

Interestingly, 77.33% ($n = 41$) of the articles consider some sort of citizen or stakeholder participation, using mainly household surveys and interviews as research methods (Figure 5). With the exception of hazard studies, the participation of citizens and stakeholders is heavily considered, regardless of the topic investigated (Figure 3). This is in contrast to previous literature reviews, which show that participation is usually disregarded in flood-related studies (de Brito & Evers, 2016; Evers, Almoradie, & de Brito, 2018).

In some cases, the input from the stakeholders was deemed a critical element in the entire process. For instance, Daré, Venot, Le Page, and Aduna (2018) adopted the Companion Modelling approach (ComMod) to identify issues of river bank cultivation, erosion, and flooding in the Upper East Region of Ghana. This involved role-playing games, participatory mapping, collaborative modelling, and a computerised agent-based model to initiate a multi-level dialogue as a means of tackling the identified issues. By using such a transdisciplinary approach, the authors enabled the creation of a cooperative decision-making environment in which trust, understanding, and mutual reliance develop over time, aiming to support innovative water governance.

Amoako et al. (2019) postulated that it is crucial to rethink FRM in Ghana by moving towards a more inclusive participatory process to enhance community capacity. In this regard, Douglas et al. (2008) argue that local capacities and initiatives can be enhanced via inter-organisational learning and collaboration, capacity building, and knowledge and resource transfer into the local communities. Training could involve encouraging participants to adopt simple flood protection measures (e.g., elevate houses, improve drainage conditions). Regarding the involvement of citizens on data collection, access to information and flood early warning systems (FEWS) can be improved through bi-directional sharing of information between FRM institutions and communities (Yankson et al., 2017).

With regard to participation and coordination within FRM institutions in Ghana, three articles mentioned in

brief the cooperation of institutions involved in FRM and DRR. Amoako and Boamah (2015), Cobbinah and Poku-Boansi (2018) and Amoako et al. (2019) reported that there are weak linkages between relevant institutions. Existing systems fail to work properly due to the lack of coordination among agencies, especially between urban planning and flood management institutions.

4 | FINDINGS ON THE CURRENT STATUS OF GHANA'S FRM BASED ON THE PARTICIPATORY APPROACH

This section summarises the main findings obtained through the online survey with 33 respondents, the stakeholder workshop with 29 key stakeholders, and 20 institutional interviews. It provides information regarding the critical regions and the main gaps for FRM in Ghana.

4.1 | Critical regions for FRM and social vulnerability enhancement

Results of both the online survey and the workshop (Figure 6) show a consensus that Accra, Kumasi, the Volta river basin and the Upper East region are the most critical regions in Ghana. Accra was mentioned 25 times by web-survey participants, followed by Kumasi ($n = 11$), and the Volta ($n = 9$) and Odaw ($n = 6$) rivers. This is in concurrence with the findings from our literature review (Section 3.2). Regarding the hazard type (Figure 6c), Accra is susceptible to coastal and urban-runoff flooding, Kumasi mainly to urban-runoff, and the Upper-East region to river flooding.

In terms of social vulnerability, workshop participants placed more emphasis on the Upper-East region (Figure 6c), confirming the literature review findings. Its high social vulnerability can be attributed to the trans-boundary nature of the river and the release from the dam in Burkina Faso. Discussions about this during the

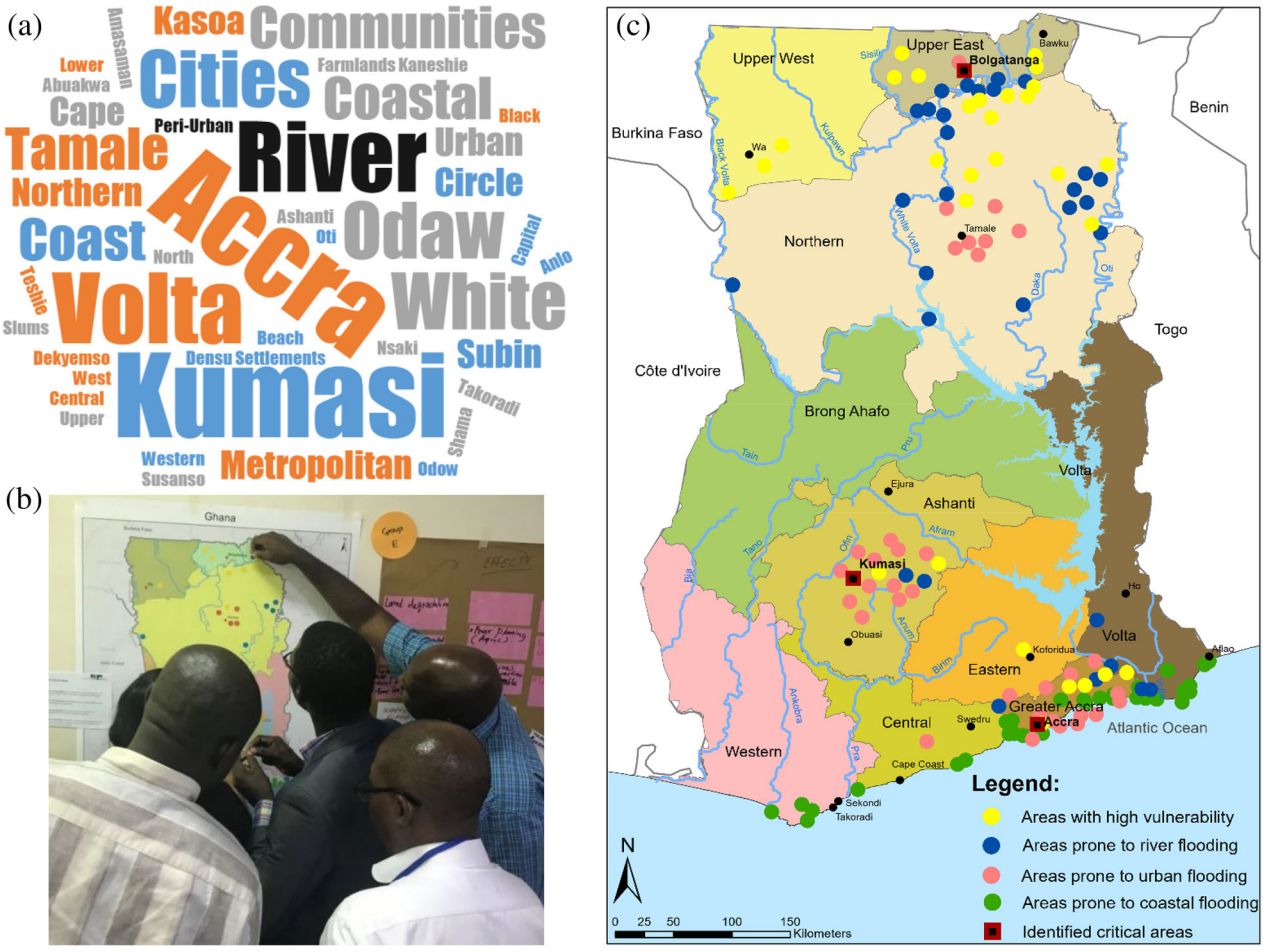

FIGURE 6 (a) Word cloud with most critical areas according to web-survey participants; (b) participatory mapping exercise during the workshop; and (c) critical areas according to workshop participants. Green dots denote areas prone to coastal floods; red to urban floods; blue to river floods; and yellow areas with high vulnerability

workshop lead to the conclusion that this situation makes the FEWS ineffective and the modelling and development of adaptation measures more complex. Given that the Upper-East is most vulnerable and both Accra and Kumasi have already been extensively studied (Section 3.2), research efforts should be directed toward the Upper East region.

4.2 | Main challenges for FRM

4.2.1 | Institutional, governance, and implementation challenges

The sustainability of the Ghanaian FRM system was criticised during the workshop and in the online survey. This criticism was due to the fact that the current FRM relies heavily on short-term intervention measures and is dependent on external funders. Key priority actions such as data collection usually stop when the projects end due to maintenance issues. This was highlighted by the case of a telemetry system that was implemented under several projects. To date, the maintenance of existing systems is challenging due to financial and technical issues. Therefore, stakeholders recommended for each institution intervening in flood risk reduction (FRR) to elaborate long-term plans with specific actions. Financial and logistical support were also found to be inadequate. Access to financial, technological, and information resources together with the ability to influence policy are considered key elements of adaptability or adaptive capacity (Smit & Wandel, 2006). Yet, most agencies rely on outside support. Moreover, since the majority of the existing projects are short-term, sustainability remains an issue.

In the workshop's focus group discussion, risk governance was reported to be too centralizatized. This was exemplified by the NADMO data transfer mechanism. Data from local and district NADMO representatives is sent to the National Head Office level for aggregation and better data management. Based on this data, decisions are made by the National Office and returned to the districts. Currently, no operational regional or local decision mechanism has been established to tackle flood emergencies. It was, however, mentioned that a regional disaster management platform was in place until 2009 but that this platform is no longer operational. Investigating the causes of this failure and building up adapted regional and local acting bodies with a certain autonomy to address FRR and FRM was deemed as crucial by the workshop participants.

One of the key findings of the workshop and the literature review (Section 3.3) is the weak institutional coordination of FRM and DRR. Existing systems fail to work properly due to the lack of coordination among agencies, especially between urban planning and flood management institutions. Currently, NADMO is driven by six technical committees (fires, disease epidemic, hydrometeorological, etc.). However, these committees only meet when a disaster occurs. There is a need to improve linkages among these committees focusing on proactive actions and the definition of guidelines for the coordination of the interaction between agencies. According to Abeka, Asante, Laube, and Codje (2019), this situation creates space for mistrust and externalisation of blame among actors. This contention is supported by the institutional interviews, which show that conflicts and misunderstandings between institutions arise due to poor coordination and unclear roles. Insufficient knowledge of the topic and different phases of FRM could also have contributed to the misperception of roles and coordination processes. Findings of the institutional interviews (Figure 7) show that some institutions have insufficient knowledge with respect to flood preparedness (15%, $n = 3$), response (20%, $n = 4$), and recovery phases (20%, $n = 4$), as well as to the operational use of early warning (30%, $n = 6$).

Regarding specific FRR laws, stakeholders reported the following gaps:

- lack of a specific law addressing flood DRR, implying that the development of regulations or a legal instrument might be a key action,
- lack of flood zone regulation. It was reported that there is an ongoing action toward the elaboration of such a regulation and a follow-up of the action should be considered,
- buffer zone regulation laws restricted to a few regions. Action aimed at applying this law at a national level was recommended and,
- lack of dumping regulation law. This was pointed out as crucial to ensure proper maintenance of the waterways. Hence, the Government's law-making body should prioritise the establishment of a dumping regulation law.

4.2.2 | Scientific and technical challenges

Reflecting similar findings from the literature review (Section 3.1), the online survey and workshop indicated that Ghana's FRM response is more reactionary than preventive and there is a need to address the weak urban planning aspect. In the workshop, stakeholders raised their concern regarding the classical approach used in

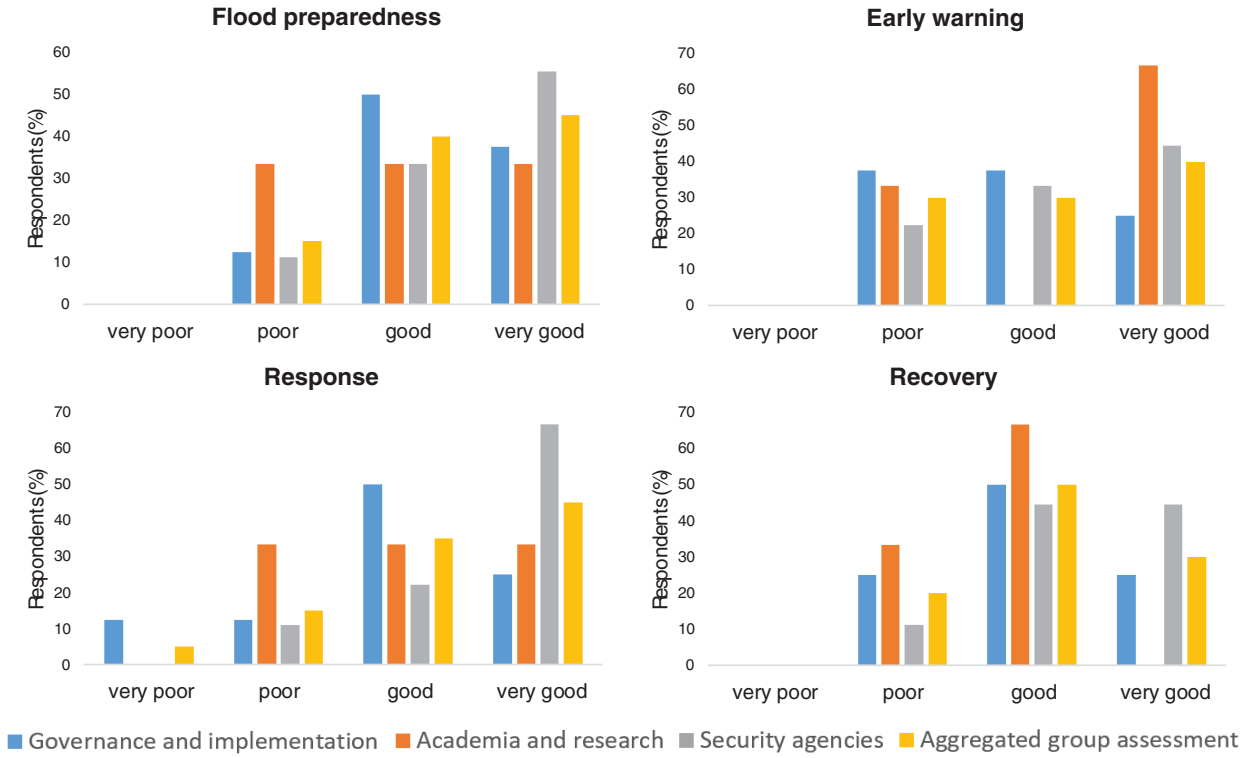

FIGURE 7 Institutional knowledge on FRM topics. Twenty institutions grouped into: governance and implementation ($n = 8$); academia and research ($n = 3$), and security agencies ($n = 9$)—results from institutional interviews

the design of water control infrastructures. In the online survey, participants expressed their dissatisfaction with the effectiveness of the existing structural and non-structural FRM measures, especially regarding spatial planning (see Figure 8). Surprisingly, of the measures evaluated, the technical capacity for public awareness programmes was considered to be well developed. This could be a reflection of ongoing projects such as the Community Resilience through Early Warning (CREW) and the Greater Accra Climate Resilient and Integrated Development Project (GARID).

Stakeholders recommended developing scenarios in the context of climate and land-use change to properly and optimally design water control infrastructures. This concern goes hand in hand with the social dimension of flood exposure, as some people consciously live in the flood-prone areas due to their risk acceptance or lack of alternatives (Cai, Haile, Magidi, Mapedza, & Nhamo, 2017). This implies that programmes should concentrate more on in-depth studies on attitude and education towards flood risk through sociological studies.

Participants in the online survey, interviews, and workshop unanimously highlighted that the hazard assessment component is not well-practiced in Ghana. This is in agreement with the literature review (Section 3.1). Even though vulnerability and hazard maps have been developed, they are restricted to a few districts (e.g., Tolon district—Unami et al., 2009; Bolgatanga and Bongo districts—Asare-Kyei et al., 2015). Critical areas such as the Upper East region were not considered. A need to develop risk maps for critical communities was, thus, requested. Aside from the development of risk maps, actions toward the prevention of reservoir siltation have already been implemented for buffer zones, but only at the local scale. Similar actions should be upscaled to the national level.

An operational FEWS is currently implemented in the White Volta and Odaw catchments and flood forecasts are available only for selected areas of the catchments (GFDRR, 2017; HKV, 2012). However, online survey results show that introducing comprehensive FEWS at a national level which addresses both river and urban flooding remains a challenge (Figure 8). Furthermore, to the best of our knowledge, there is no flood decision support system (fDSS) in place that integrates the FEWS with FRM response.

In the workshop's focus group discussion, the participants mentioned that the coarse resolution of current hydrological–hydrodynamic models for flood forecasting hinders the formulation of proper flood risk warnings and that attempts to run models at a finer spatial resolution are hampered by the run time due to limited

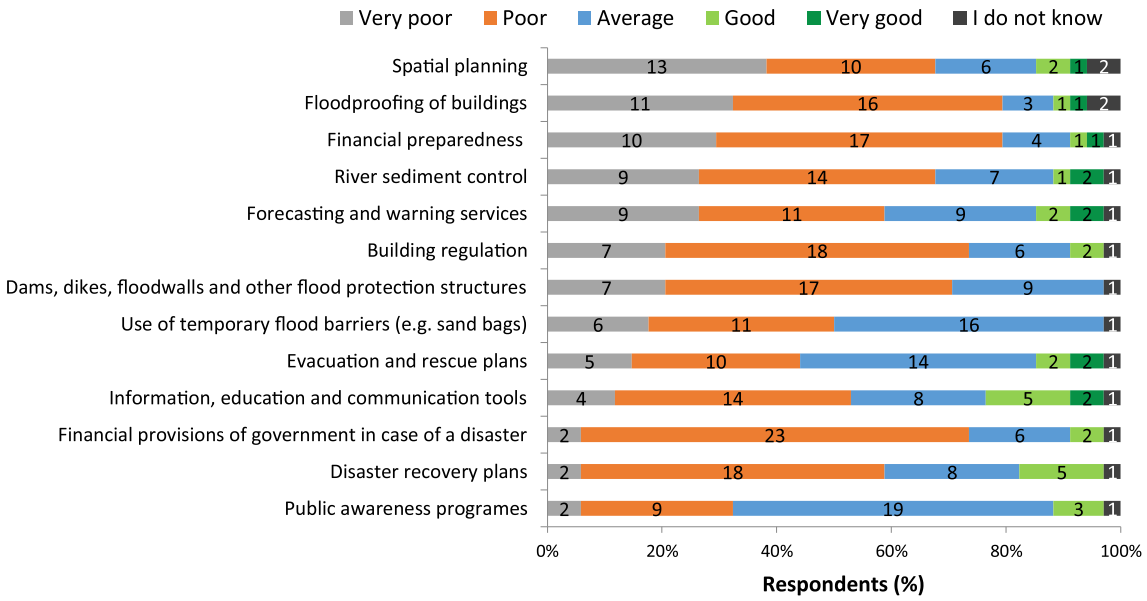

FIGURE 8 Effectiveness of existing structural and non-structural FRM measures according to online survey. Participants ($n = 33$)

computing capacity and data availability. Moreover, participants recommended improving the lead-time and the spatio-temporal resolution of meteo-hydrological models (e.g., efficiently and effectively couple the weather forecast and hydrological models).

Results of the online survey and the literature review (Section 3.1) show that, up to now, there have been no studies about cascading disasters caused by floods in Ghana. Accra and Kumasi are dynamic cities and both are vital to Ghana's economy. Hence, the effect of cascading disasters on its critical infrastructure (roads, bridges, power stations, health facilities) could shut down the city, exacerbating an already dire situation. This may cause more casualties due to massive unrest and health-related epidemics.

4.2.3 | Social capacity challenges

Based on the online survey, even though progress has been made in terms of coordination with communities, in some cases, there is weak dissemination of flood risk and warning information (Figure 8). This is particularly the case for the releases from Bagré Dam in Burkina Faso (FLOODLIST, 2018). Stakeholders from the workshop pointed out that there has been collaboration and cooperation between the operators of Bagre Dam and their Ghanaian counterparts. There are, however, limitations in disseminating the information in a timely manner. Moreover, despite the existence of a bilateral Burkina Faso-Ghana management committee of the dam (i.e., a joint technical committee of the Volta Basin Authority and a local transboundary committee), spillage results in significant damages in Ghana. Similar consequences are observed with the spillage of the Weija dam in Accra. Communication types and channels must be strengthened. Based on the interviews, the most effective and preferred channel of communicating warnings is the media (television and radios), followed by mobile-social networks (WhatsApp and SMS), website and newsletters. Overall, the choice of these channels of communication is due to their capacity to promptly reach the general public.

Despite the challenges, some advances have also been made. Findings from the workshop's focus group discussion show that several socio-strategies (i.e., risk awareness and coping mechanisms) are in place during floods and for the preflooding and postflooding event periods. However, the challenge is their sustainability and accessibility to all the vulnerable groups in the country. Furthermore, since citizens rely mostly on family networks during floods, future interventions should focus on increasing the adaptive capacity of households by improving livelihood opportunities for residents and expanding access to basic needs (Yankson et al., 2017). Implemented strategies include:

- Plans are made in advance to include disaster management at the district assembly level;
- Cultivation of flood-resistant crop varieties as well as early maturing crops that are harvested before the floods is promoted;
- Education on FRM, waste separation, reuse, and sustainability at various levels and by various organisations (e.g., schools, religious bodies). Nevertheless, workshop participants stated that community education is only conducted occasionally;

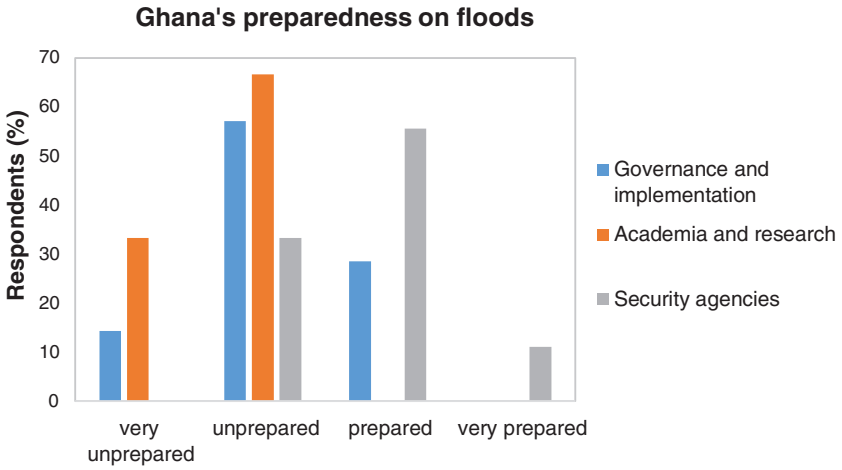

FIGURE 9 Ghana's preparedness for flood occurrences according to the institutional interviews ($n = 20$) grouped into: governance and implementation ($n = 8$); academia and research ($n = 3$), and security agencies ($n = 9$)

- Climate volunteers have been formed within the communities. They are trained to respond to disasters at the local level. An example is climate volunteers from the Red Cross.

In summary, the presented challenges in governance, scientific-technical and social aspects reflect the overall unpreparedness of the country with respect to floods according to interview participants (Figure 9). In general, there was a tendency for academia and research participants to rate the preparedness levels lower than, for instance, security agencies.

5 | WAYS FORWARD AND OPPORTUNITIES FOR IMPROVEMENT

5.1 | Enhancing socio-technical capacity and resilience

In Section 4.2, it was shown that data acquisition from local monitoring stations and maintenance of this data remains a challenge for financial and technical reasons. During the plenary session of the workshop, a suggested solution to the data collection issue was to design data collection systems in associations of local people (e.g., district assemblies) through the use of citizen science (Marchezini et al., 2018). This would have the advantage that it would solve the lack of human capacity, increase awareness and sense of ownership and would ensure proper maintenance of equipment. It was also pointed out that the use of satellite data can be a valid alternative solution to address the scarcity of in situ observation data. Overall, workshop participants supported the view that structured and intersectoral collaboration is needed to address flood risk. Creating a data-sharing platform, leveraging the potential of smartphone-based apps, individual action, dedicating part of the national budget to FRR, and capacity building are all required to strengthen FRR in Ghana.

Based on the institutional interviews, the most important needs or measures to increase the capacity for dealing with floods were identified (Figure 10). The most cited measures to mitigate flood risk are the improvement of the FEWS (80%, $n = 16$), the building of flood-proof infrastructure (65%, $n = 13$), public information (60%, $n = 12$), and development of adaptation plans (50%, $n = 10$). These measures and mechanisms should be established within different levels, from the community to the institutional level, to increase their coping capacities and resilience.

During the workshop plenary session and from the institutional interviews, stakeholders identified that there is a need to implement:

- women's institutions within the communities as women are often proactive at communicating information and taking actions when they are made aware of impending disasters,
- an insurance system for farmers who may lose their livelihood due to the flooding. Currently, the government is working towards ensuring small-holders' capacity to cope with their losses,
- a reliable FEWS by using the state-of-the-art technologies with local monitoring stations and building the personnel capacity,
- warning systems with feedback mechanisms within the communities,
- emergency operation centers (EOC) in vulnerable areas. Existing EOCs are often reactive and should be constantly assessed to properly handle future occurrences,

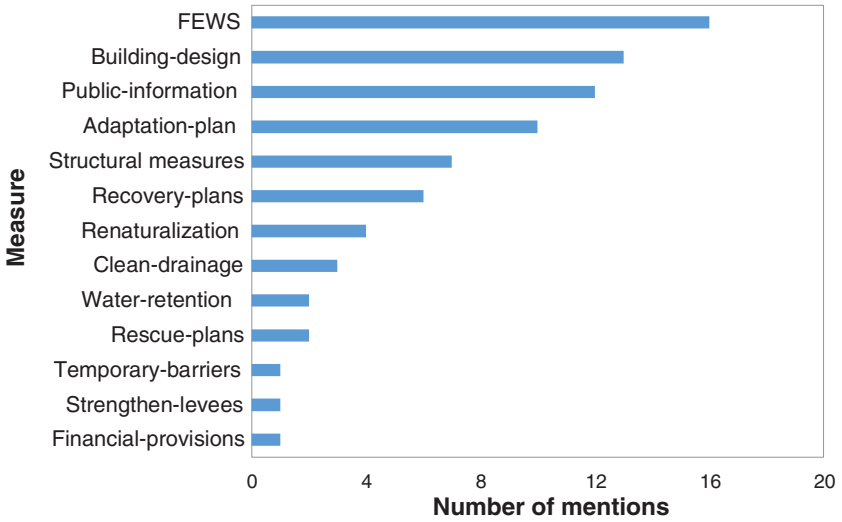

FIGURE 10 Flood measures and needs to be addressed according to institutional interviews ($n = 20$). The participants were able to choose more than one option

- continuation and expansion of the DRR simulation exercises in high-risk areas. Assessments should also be made and reported after the exercise so stakeholders are duly informed about the strengths and weaknesses of the DRR so as to identify ways to improve it,
- construction of dams, reservoirs and retention basins to store excess water from floods to be used in dry periods and,
- provision of flood-proof infrastructures and building of houses in elevated areas.

Furthermore, institutions involved in FRM and DRR should be trained in state-of-the-art tools. These include flood hazard and risk modelling and mapping, flood forecasting and decision support systems, search and rescue, disaster risk management, GIS and data management, response simulation and policy implementation.

5.2 | Stakeholder engagement through participatory FRM—A tool for social learning

The internal conflicts (Section 4.2) and the external issues need to be addressed in an interdisciplinary and transdisciplinary approach. Ghana's stakeholder engagement (Section 3.3) has become a pillar for enhancing its institutional and social capacity in dealing with flood risk. As a step forward, it is perceived that social learning can be used to further strengthen the country's and stakeholders' capacities. In a setting involving different societal and administrative levels, this can effectively enhance resilience and allow for a more sustainable implementation of the planned measures (Evers et al., 2016, 2018; Watson et al., 2009; Weddfelt, Vaccari, & Tudor, 2016).

Additionally, social learning can be realised through the concept of citizen science. In data-scarce areas like Ghana, the use of citizen science to collect local climate data could help to disseminate information and increase awareness of flood-related issues among participants. The good coverage of mobile access in Ghana (Owusu-Ansah, 2016) could be used to provide timely warning and receive vital information from communities during floods and in preflooding and postflooding periods (Marchezini et al., 2017).

5.3 | Governance and policies

Based on the findings in Section 3.1 and 4.2, we found that the roles of some institutions in the management of floods in Ghana are incoherent or unclear. Hence, it is worth investigating the policy area of FRM and DRR, in particular, the existing institutional framework, actors and policy integration. Further, the policy network should be analysed, focusing on interdependencies between government, public authorities and other societal actors, to understand how FRM and DRR policies and strategies have developed and why they led to the current outcomes (Rhodes, 2008). This will help to identify starting points for enhancing the policy network to strengthen Ghana's FRM and DRR governance, policy and management, aligning them with the Sendai Framework priorities.

This study has delved into the identification of actors, the drivers, the pressures and the interactions of institutions on FRM and DRR. However, we did not investigate in detail the causality and the most sensitive variables that influence decision making. Using the DPSIR framework (Giupponi, Sgobbi, Mysiak, Camera, & Fassio, 2008) and qualitative system dynamics (García-Santos

et al., 2018; Höllermann & Evers, 2019) would make it possible to analyse this causality in detail, providing a comprehensive understanding of the dynamics of interactions among institutions, communities, and floods. The output-causal diagram could help in making targeted decisions to improve institutional functions and/or social and technical capacity.

As a guiding concept of participatory governance, questions should focus on empowerment and capacity building as well as social equity and political representation. This will also strengthen stakeholder involvement in FRM and DRR (Fischer, 2012). The use of scenario techniques could help identify policy options for a participatory FRM and DRR (Kok, van Vliet, Bärlund, Dubel, & Sendzimir, 2011).

6 | CONCLUSION

Ghana's FRM is multifaceted, involving different actors, drivers, and pressures. Based on the review of 53 articles and a participatory process including an online survey, a workshop with 29 stakeholders and interviews with 20 key institutions, it was found that several socio-technical strategies are in place for dealing with floods in Ghana; these include FEWS in some communities, programmes for increasing public awareness and vulnerability maps for selected areas. The municipalities of Accra, Kumasi and the Upper East region were identified as the most critical regions, with relatively few studies conducted in the White Volta and Black Volta river basins. Hence, the potential exists to investigate flood risk in these areas as well as at the national level. Overall, research conducted in Ghana was mainly participative and inclusive, which highlights the willingness of citizens to contribute to FRM.

Our findings suggest that the measures taken to address flooding in Ghana are mostly reactive rather than preventive. Due to climate change, uncertain extreme events and rapid urbanisation, integrated FRM considering both short-term and long-term planning should be given priority in policies and action plans. Research should be done on (a) the development of sustainable solutions such as the enhancement of community adaptation strategies, (b) understanding the dynamics and impacts of cascading disasters on critical infrastructure in large cities (e.g., Accra and Kumasi), (c) strengthening of the institutions mandates and functions, and (d) the use of state-of-the-art methodologies such as recent remote sensing technology and Earth Observation data (Giustarini, Chini, Hostache, Pappenberger, & Matgen, 2015) to improve flood hazard mapping and FEWS.

Whilst making a targeted decision to improve FRM in Ghana, it is worth considering and building upon existing laws and policies. The National Water Policy (Government of Ghana, 2007) and the Blue Agenda (Addo & Danso, 2017) provide groundwork for FRM. They already address some major components of FRM and DRR, such as adopting FEWS, buffer zone laws, building regulations and encouraging public education and community consultation in the implementation of measures. This is a good indication that Ghana's FRM policies are directed towards stakeholder engagement in the decision-making process; however, it should move towards more inclusive participation, from the planning to the management stages. This would enhance resilience and improve the sustainable implementation of measures.

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DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article The other data that support the findings of this study are available from the corresponding author upon reasonable request.

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APPENDIX A: INSTITUTIONAL SURVEY

General questions

1. Please indicate the highest degree/qualification you have completed
   () College/pre-university (e.g., high school)
   () Undergraduate (e.g., BA, BSc)
   () Master (e.g., MsC, MA)
   () Doctor (e.g., MPhil, PhD)
   Other:
2. Please indicate your academic background
3. Rate your knowledge about the following topics:

   Flood preparedness.
   () very good.
   () good.
   () poor.
   () very poor.

   Early warning.
   () very good.
   () good.
   () poor.
   () very poor.

   Response.
   () very good.
   () good.
   () poor.
   () very poor.

   Recovery.
   () very good.

() good.
() poor.
() very poor.

1: Data, modelling and risk assessment and analysis
1.1: Data collection: hydrological, land-use, climate, socio-economic, interviews and surveys

4. Which hydroclimatic, climatic, socio-economic, and other spatial data are available? For what time period and scale? How can they be accessed?
   DataPeriodScale
   () weather forecast.
   () runoff.
   () precipitation.
   () soil maps.
   () land use and land cover.
   () income.
   () age.
   () literacy rate.
   () roads.
   () hospitals and health care facilities.
   () water treatment stations.
   () shelter.
   Other:
5. Is there a hydroclimatic instrumentation plan at local or national level?
6. How many hydroclimatic instruments are manually and tele-transmitted?
7. How often data from the hydroclimatic instruments are accessed?
8. What are the main needs in terms of hydroclimatic monitoring?

1.2: Modelling: hydrological and hydrodynamic flood modelling, socio-economic and policy modelling

9. Does the institution undertake or have expertise in flood modelling? Which kind of experience?
10. Which hydrological and hydraulic models do you use? What is the spatial and temporal resolution?
11. What is the current forecast lead time? Do you desire an improvement in the lead time? Can the lead time be improved?

1.3 Disaster and risk assessment and analysis

12. Rank the different flood types based on their occurrence in Ghana (1: more frequent; 4: less frequent):
    () flash floods.
    () fluvial floods.
    () coastal floods.
    () urban floods.
13. Do you carry out post disaster needs assessments after the occurrence of floods? If yes, when after the floods?
14. Is there a flood events database? If yes, how are the damages of these events recorded?
15. Are there socio vulnerability maps available for the country or in a given basin/district?
16. Are there studies assessing the flood risk in the country or in a given basin/district?
17. Which method is applied for assessing flood risk?
18. Which components of flood risk are considered?
    () hazard (level and/or intensity)
    () vulnerability.
    () exposed elements.
    () resilience of the exposed elements.
    other:
19. What is your level of satisfaction with the existing risk studies?
    () very satisfied.
    () satisfied.
    () dissatisfied.
    () very dissatisfied.

2: Scenario, prevention and adaptation strategies development
2.1 Scenarios: land-use and climate change scenarios

20. Is there any land use scenario developed for the country? If yes, How can one have access?
21. Who is responsible for landuse and land cover monitoring? When is this information updated?
22. What are the key elements that should be considered while developing land use scenarios for Ghana?
23. Are there climate scenarios (Representative Concentration Pathway) officially used for Ghana? If yes why?

2.2 Disaster scenarios

24. Has the country experienced cascading disasters triggered by a flood event?
25. What are the relationships and interdependencies among critical infrastructures during the occurrence of cascading disasters?
26. Which critical infrastructures are most vulnerable (e.g., energy sector, water supply, roads) in the case of cascading disasters?

2.4 Participatory prevention and adaptation strategies development

27. What are the current prevention and adaptation measures for floods applied in the country?
28. What prevention and adaptation measures do you think would be most effective for reducing flood losses in Ghana? Choose a maximum of 4 measures
    () development of forecasting and warning services.
    () inform the public about flood risks and their mitigation.
    () regulate the construction of buildings by considering a water sensitive design.
    () create flood risk adapted land-use plans.
    () renaturalization of parts of the rivers.
    () heightening and strengthening the existing levees.
    () build dams, dikes and floodwalls.
    () develop disaster recovery plans.
    () provide financial provisions in case of disasters.
    () elaborate evacuation and rescue plans.
    () maintain the existing drainage systems.
    () use of temporary flood barriers (e.g., sand bags)
    () improve water retention in agricultural areas.
    Others:
29. Are there spatial management plans (National, district etc.) available?
30. How prepared is the country to address the flood issue?
    () very prepared.
    () prepared.
    () unprepared.
    () very unprepared.

3: Flood risk governance

3.1 Participatory flood risk governance assessment

31. What national and regional laws and policies are governing flood risk management in Ghana? Please list them if possible with reference.
32. How are these laws and policies implemented and by who? Please comment referring to the laws and policies listed in 33.
33. How would you evaluate the laws and policies and their implementation?
34. Which challenges are you facing in its implementation? Any recommendations for improvement?
35. Which of the following strategies are used to govern floods in Ghana? You can choose more than one strategy.
    () government regulations and policies.
    () community-based, participatory approaches.
    () market-based mechanisms such as environmental taxes and tradable permits.
    () market incentives.
    () pressure from the public and NGOs on private businesses to change practices.
    Other:
36. Which actor groups and stakeholders are responsible for the existing flood risk management (considering government, public authorities, societal actors, economic actors)?
37. Which actor groups and stakeholders are affected (positively or negatively) by the existing flood risk management?
38. Are any actor groups and stakeholders missing for effective and just flood risk management (not included, not participating, not benefiting by the existing flood risk management)? If yes, please list them.
39. What kind of conflicts arise or have occurred within the existing flood risk management practice? Please give examples, if possible with a reference to place and date.
40. Who is affected by the existing conflicts in flood risk management practice? How are conflicts facilitated / solved? Please give examples, if possible with a reference to place and date.

4: Human-Floods Dynamics and Stakeholder participation

4.1 Human-floods dynamics

41. What are the most serious negative consequences of floods in Ghana? Choose a maximum of 4 consequences.
    () Decrease in tourism.
    () Damage to properties and contents.
    () Deterioration of health conditions.
    () Loss of lives.
    () Damage to critical infrastructure and public buildings.
    () Damage to livestock and crops.
    () Disruption of transport services.
    () Decrease of purchasing and production power.
    () Population displacement.
    () Business interruption.
    () Property values decrease in endangered areas.
    () Pollution is spread by flood waters.
    () Damage to cultural or heritage sites.
    () Ecological damage.
42. How do humans influence the occurrence of floods in Ghana?
43. What are the main factors that aggravate flood losses in Ghana? Choose a maximum of 4 factors.
    () Too many people live in flood risk areas.

() Exposed people do not take sufficient measures to prevent losses.
() Levees have not been properly maintained.
() The warning systems are not good enough.
() Flood risk management organisations do not have sufficient resources.
() Climate change.
() The building of dams has changed the water runoff pattern.
() Neighbouring countries do not take sufficient measures to reduce flooding downstream.
() Levees are not sufficiently high and strong.
() Deforestation.
() Authorities have issued building permits for areas where the flood hazard is high.

44. What are the past and current impacts of population growth, land use change and urbanisation on flood characteristics (occurrence, intensity, duration)?
45. How do you see the future interaction between floods and humans?

4.2 Stakeholder participation

46. Which government, public authority, NGO, company and other societal actors do you collaborate and work with?

5: Integrated disaster risk management mechanism technical tools

5.1 FEWS: citizen science

47. Is there any flood early warning system implemented by your institution?
48. If yes, describe its performance in meeting its intended purpose.
    () very good performance.
    () good performance.
    () poor performance.
    () very poor performance.
    () comments:
49. Are you aware of any tools used to disseminate FEWS in Ghana?
50. What are the different components considered in the implemented FEWS? What are the organisations responsible for each component? Any component that should be improved?
51. Is the community involved in the implementation of FEWS? How do you judge their level of involvement?
    () very high participation.
    () high participation.
    () low participation.
    () very low participation.
    () comments:
52. What are the associated challenges, successes, areas of improvement and needs for reinforcement?
53. Rank the best way of disseminating flood early warning information (1: best; 4: worst):
    () media.
    () social network.
    () website.
    () newsletters.
    Other:

5.3 GaPS-fDSS

54. Is there any flood decision support system (FDSS) available online for accessing information related to flood early warning at district, basin and country level?
55. If yes, how satisfactory are the services provided by these FDSSs?
    () very satisfactory.
    () satisfactory.
    () unsatisfactory.
    () very unsatisfactory.
56. Do you know any component of FDSS that needs to be improved? Or added?

6: Capacity development

6.1 Community coping capacity

57. Which of the following strategies are most used by individuals to cope with floods in Ghana? Choose a maximum of 3 strategies.
    () Livelihood diversification.
    () Elevate land before building.
    () Cleaning of gutter and drainage systems.
    () Temporary seeking refuge.
    () Use of sandbags and stone bags.
    () Transfer valuables to neighbours or friends/family.
    () Place valuables on shelves or on higher levels.
    () Using indigenous knowledge for assessment of risks, weather forecasting and early warning.
    () Receiving external support from government and others to cope.

6.2 Training of specialist, decision and policy makers

58. What are your needs for capacity building in flood risk reduction and management?

59. What would be your overall expectations if trainings were to be organised to strengthen your (or the members of your institution) skill in flood risk reduction and management?
60. What type of specialist is needed for your institution to improve FRM?

7: Sustainable implementation of risk policy, strategies and mechanism

61. How are Flood Risk Reduction (FRR/FRM) plans financed?
62. How is the national FRR policy interlinked to the ECOWAS Disaster Risk Reduction Policy?

APPENDIX B: SUMMARY OF STUDIES INCLUDED IN THE REVIEW

Authors	Year	Title	Journal	Study area	Spatial scale	Context of the problem	Stakeholders participation
Abeka et al.	2019	Contested causes of flooding in poor urban areas in Accra, Ghana: An actor-oriented perspective	Environment, development and sustainability	Accra (Glefe, Mpoase, and Agbogbloshie communities)	Local	Risk perception	Yes
Abu and Codjoe	2018	Experience and future perceived risk of floods and diarrheal disease in urban poor communities in Accra, Ghana	International journal of environmental research and public health	Accra (James town and Agbogbloshie communities)	Local	Risk perception	Yes
Addo	2015	Monitoring sea level rise-induced hazards along the coast of Accra in Ghana	Natural hazards	Accra (coast)	City	Hazard	No
Addo and Danso	2017	Sociocultural factors and perceptions associated with voluntary and permanent relocation of floodvictims: A case study of Sekondi-Takoradi Metropolis in Ghana	Jambá: Journal of disaster risk studies	Sekondi-Takoradi (Eshiem, Kansawurodo and Whindo communities)	Local	Risk perception, coping capacity	Yes
Addo et al.	2011	Impacts of coastal inundation due to climate change in a CLUSTER of urban coastal communities in Ghana, West Africa	Remote sensing	Panbros, Grefi and Gbegbeyise communities	Local	Risk, vulnerability, risk perception, adaptation strategies	Yes
Addo et al.	2018	Drone as a tool for coastal flood monitoring in the Volta Delta, Ghana	Geoenvironmental disasters	Volta Delta (Fuvemeh community)	Local	Susceptibility	No
Afriyie et al.	2017	"The floods came and we lost everything": Weather extremes and households' asset vulnerability and adaptation in rural Ghana	Climate and development	Central Gonja District (Buipe and Yapai communities)	Local	Vulnerability, coping capacity, and adaptation strategies	Yes
Amoako	2016	Brutal presence or convenient absence: The role of the state in the politics of flooding in informal Accra, Ghana	Geoforum	Accra (Agbogbloshie, old Fadama and Glefe communities)	Local	Flood risk management	Yes
Amoako	2017	Emerging grassroots resilience and flood responses in informal settlements in Accra, Ghana	GeoJournal	Accra (Agbogbloshie, old Fadama and Glefe communities)	Local	Vulnerability, adaptive capacity, risk perception	Yes
Amoako and Inkoom	2017	The production of flood vulnerability in Accra, Ghana: Re-thinking flooding and informal urbanisation	Urban studies	Accra (Agbogbloshie, old Fadama and Glefe communities)	Local	Vulnerability, risk perception	Yes
Amoako and Boamah	2015	The three-dimensional causes of flooding in Accra, Ghana	International journal of urban sustainable development	Accra	City	Susceptibility	Yes
Amoako et al.	2019	Complex twist of fate: The geopolitics of flood management regimes in Accra, Ghana	Cities	Accra (Agbogbloshie and old Fadama communities)	Local	Flood risk management	Yes
Amoateng et al.	2017	A multi-faceted analysis of annual flood incidences in Kumasi, Ghana	International journal of disaster risk reduction	Kumasi (Kronum, Asuoyeboa, Dichemso, Moshie Zongo, Atonsu, Ahinsan, Kokode and Adiembra communities)	Local	Susceptibility, vulnerability, and flood risk management	Yes
Amoateng et al.	2018	Dwindling rivers and floodplains in Kumasi, Ghana: A socio-spatial analysis of the extent and trend	Applied geography	Kumasi	City	Landuse analysis	Yes

(Continues)

Authors	Year	Title	Journal	Study area	Spatial scale	Context of the problem	Stakeholders participation
Antwi et al.	2015	Community vulnerability assessment index for flood prone savannah agro-ecological zone: A case study of Wa West District, Ghana	Weather and climate extremes	Wa West District (Chietanga, Baleufili, Bamkpama and Zowayeli coomunities)	Local	Vulnerability	Yes
Antwi-Agyei et al.	2018	Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana	Climate risk management	Central Gonja District (Lito, Kusawgu and Yapei-Yipala VILLAGES)	Local	Adaptation strategies, coping capacity, susceptibility	Yes
Antwi-Boasiako	2016	Insurance and flood risk reduction in Ghana: Do insurers penalise homeowners who take precautionary measures?	Environmental hazards	Accra	City	Flood insurance	No
Antwi-Boasiako	2017	It is beyond my control: The effect of locus of control orientation on disaster insurance adoption	International journal of disaster risk reduction	Accra	Local	Flood insurance, risk perception	Yes
Armah et al.	2010	Impact of floods on livelihoods and vulnerability of natural resource dependent communities in northern Ghana	Water	Gonja region (Boinya and Daboya communities	Local	Coping capacity, adaptive strategies, vulnerability	Yes
Asare-Kyei et al.	2015	Modelling flood Hazard zones at the Sub-District level with the rational model integrated with GIS and remote sensing approaches	Water	Vea watershed (Bolgatangaand bongo districts)	Regional	Hazard	Yes
Asare-Kyei et al.	2017	Development and validation of risk profiles of west African rural communities facing multiple natural hazards	PLoS ONE	Vea watershed	Regional	Risk and vulnerability	Yes
Asiedu	2018	Assessing the threat of erosion to nature-based interventions for Stormwater management and flood control in the Greater Accra metropolitan area, Ghana	Journal of ecological engineering	Accra	Regional	Soil erosion, susceptibility	No
Bempah et al.	2017	The role of social perception in disaster risk reduction: Beliefs, perception, and attitudes regarding flood disasters in communities along the Volta River, Ghana	Disaster risk reduction	Northern region - white and black Volta (Buipe, Nawuni, Kubori, Yagaba communities)	Local	Risk perception	Yes
Boateng et al.	2017	Mapping vulnerability and risk of Ghana's coastline to sea level rise	Marine geodesy	Entire coastal region	Regional	Susceptibility, vulnerability	No
Campion und Venzke	2013	Rainfall variability, floods and adaptations of the urban poor to flooding in Kumasi, Ghana	Natural hazards	Kumasi (Atonsu, Ahensan, Asokore Mampong, Atonsu, Dakwadwom and Kwadaso Estates communities)	Local	Susceptibility, adaptation strategies	Yes
Cobbinah and Poku-Boansi	2018	Towards resilient cities in Ghana: Insights and strategies	Futures	Accra and Kumasi	City	Resilience, urban planning	Yes
Codjoe and Afuduo	2015	Geophysical, socio-demographic characteristics and perception of flood vulnerability in Accra, Ghana	Natural hazards	Accra (James town, Ussher town, and Agbogbloshie)	Local	Susceptibility, risk perception	Yes

Authors	Year	Title	Journal	Study area	Spatial scale	Context of the problem	Stakeholders participation
Codjoe and Issah	2015	Cultural dimension and adaptation to floods in a coastal settlement and a savannah community in Ghana	GeoJournal	Accra (James town) and tamale (Dungu community)	Local	Adaptation strategies	Yes
Codjoe et al.	2017	Environmental hazard and migration intentions in a coastal area in Ghana: a case of sea flooding	Population and environment	Volta Delta (Anyakpor, Ocanseykope and Ada-Foah communities)	Local	Migration intentions, risk perception	Yes
Danso and Addo	2016	Coping strategies of households affected by flooding: A case study of Sekondi-Takoradi Metropolis in Ghana	Urban water journal	Sekondi-Takoradi (Eshiem, Kansawurodo and Whindo communities)	Local	Risk perception, coping capacity	Yes
Dare et al.	2018	Problemshed or watershed? Participatory Modelling towards IWRM in North Ghana	Water	Upper east region, white Volta Basin	Regional	Flood risk management	Yes
Darkwah et al.	2018	Contextualising urban resilience in Ghana: Local perspectives and experiences	Geoforum	Kumasi (Sisaakyi, Ahinsan estate and Asawase communities)	Local	Resilience	Yes
Djimesah et al.	2018	Influential factors in creating warning systems towards flood disaster management in Ghana: An analysis of 2007 northern flood	International journal of disaster risk reduction	Northern region - white Volta	Regional	Early warning system	Yes
Frick-Trzebitzky et al.	2017	Crafting adaptive capacity: Institutional Bricolage in adaptation to urban flooding in Greater Accra	Water alternatives	Densu Delta (Glefe and Tetegu)	Regional	Adaptation strategies	Yes
Frick-Trzebitzky et al.	2017	Institutional bricolage and the production of vulnerability to floods in an urbanising delta in Accra	International journal of disaster risk reduction	Densu Delta (Glefe and Tetegu)	Regional	Vulnerability, adaptation strategies, risk perception, institutional analysis	Yes
Logah et al.	2017	Floodplain hydrodynamic modelling of the lower Volta River in Ghana	Journal of hydrology: Regional studies	Lower Volta River (Akosombo and Kpong dams)	Regional	Hazard	No
Ngwese et al.	2018	Traditional and local knowledge practices for disaster risk reduction in northern Ghana	Sustainability	Chietanga and Yoggu communities	Local	Adaptation strategies, coping capacity, risk perception	Yes
Oku et al.	2015	Role of soil properties and precipitation concentration in enhancing floods in northern Ghana	European journal of sustainable development	Navrongo and tamale	City	Susceptibility	No
Olwig	2012	Multi-sited resilience: The mutual construction of “local” and “global” understandings and practices of adaptation and innovation	Applied geography	Northern Ghana	Regional	Resilience	Yes
Osman et al.	2016	Vulnerability and risk levels of communities within Ankobra estuary of Ghana	International journal of disaster risk reduction	Ankobra estuary (Asanta and Sanwoma communities)	City	Vulnerability, exposure, risk	Yes
Owusu et al.	2013	Reservoir storage for managing floods in urban areas: a case study of Dzorwulu basin in Accra	Hydrological processes	Accra (Dzorwulubasin)	City	Hazard, reservoir management	No
Owusu-Ansah	2015	The influences of land use and sanitation infrastructure on flooding in Kumasi, Ghana	GeoJournal	Kumasi (Kumasi airport and ash town)	City and local	Susceptibility and flood risk management	Yes
Owusu-Ansah et al.	2018	Flood vulnerability and coping mechanisms around the Weija dam near Accra, Ghana	GeoJournal	Accra (Weija dam)	Local	Vulnerability, coping capacity, urban planning	Yes

(Continues)

Authors	Year	Title	Journal	Study area	Spatial scale	Context of the problem	Stakeholders participation
Quarshie et al.	2018	"It was touching": Experiences and views of students in the June 3 flood and fire disaster relief response volunteerism in Accra, Ghana	Cogent psychology	Accra	City	Mental healthcare emergency response	Yes
Songsore	2017	The complex interplay between everyday risks and disaster risks: The case of the 2014 cholera pandemic and 2015 flood disaster in Accra, Ghana	International journal of disaster risk reduction	Accra	City	Compound disasters, cholera outbreaks	No
Tambo	2016	Adaptation and resilience to climate change and variability in north-East Ghana	International journal of disaster risk reduction	Bongo, Kassena Nankana east and Kassena Nankana west districts	Local	Adaptation strategies, resilience	Yes
Tauhid et al.	2018	Mitigating climate change related floods in urban poor areas: Green infrastructure approach	Journal of regional and City planning	Accra (old Fadama)	Local	Adaptation strategies	No
Tschakert et al.	2010	Floods in the Sahel: An analysis of anomalies, memory, and anticipatory learning	Climatic change	Kete Krachi, Wenchi, and Navrongo	Regional	Adaptation strategies, flood disasters inventory	Yes
Twum and Abubakari	2019	Cities and floods: A pragmatic insight into the determinants of households' coping strategies to floods in informal Accra, Ghana	Jambá: Journal of disaster risk studies	Accra (Alajo community)	Local	Coping capacity, adaptive strategies	Yes
Unami et al.	2009	Case study: Hydraulic Modelling of runoff processes in Ghanaian inland valleys	Journal of hydraulic engineering	Tolon/Kumbungu District	Regional	Hazard	No
Unami et al.	2010	A stochastic differential equation model for assessing drought and flood risks	Stochastic environmental research and risk assessment	Kade, Legon, gung	Regional	Hazard	No
Yankson et al.	2017	Assessment of coastal communities' vulnerability to floods using indicator-based approach: a case study of Greater Accra metropolitan area, Ghana	Natural hazards	Accra (Gbebgeyise, James town, Korle Gonno, Osu, La, Teshie and Nungua, Tema New Town, Kpone, Bortiano and Oshiyie)	Local	Vulnerability	Yes
Yiran and Stringer	2016	Spatio-temporal analyses of impacts of multiple climatic hazards in a savannah ecosystem of Ghana	Climate risk management	Uppereast region (Bawku, Kubore, Kumpalgoga, Bolgatanga, bongo, Sandema, Fumbisi, Tempane, Navrongo, Kayoro, Nagodi, Koose, Pwalugu)	Local	Flood impacts, flood disasters inventory	Yes