Review article

A systematic review of Community Engagement (CE) in Disaster Early Warning Systems (EWSs)

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ABSTRACT

Engaging the community in Early Warning Systems (EWSs) plays an essential role in saving lives, reducing injuries, and limiting environmental damage associated with disaster events. However, EWSs have traditionally focused on technology and infrastructure with the absence of comprehensive engagement with the community across the four EWS elements of risk knowledge, monitoring, dissemination and communication and response capability. Subsequently, past experience shows inappropriate responses by communities during disasters.

This study reviews definitions, concepts and evolution of EWSs, and the applicability of Community Engagement (CE) in EWSs. It aims to systematically review how the community is engaged in the four elements of EWSs using evidence from the literature sourced from peer-reviewed articles and grey literature. From a total of 4211 initial documents sourced from 2008 to 2018, 31 documents (15 peer-reviewed journal articles and 16 grey literature from project reports) were finally selected to review after an extensive screening process. Of the 31 documents, most of them were from Low- and Middle-Income Countries (LMICs) especially the Asian region, followed by the African region. The findings indicate inadequate CE across the four EWS elements (dominating in the risk knowledge element with a single hazard focus). Identified key issues included challenges for sustainability of CE in EWSs, inadequate integration of local and scientific knowledge into EWS design and operation and insufficient consideration of the full range of vulnerable groups in the system. More systematic and sustained efforts are required to improve CE in all EWS elements in order to achieve more effective disaster response.

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1. Introduction

Early Warning Systems (EWSs) are a key part of disaster preparedness [1,2]. They are considered an essential component providing timely and effective information to individuals and communities so that immediate, appropriate and effective responses can be taken to reduce potential injury and deaths, and damage to property and livelihoods [3,4]. The importance of EWSs has been repeatedly emphasized in major international agendas like the Yokohama strategy in 1999, the Hyogo Framework for Action in 2005 and the Sendai Framework for DRR in 2015–2030 [5].

According to the 2006 reports of the United Nations for Disaster Risk Reduction (UNDRR) [6] and United Nations (UN) [3], an EWS consists of four important elements: risk knowledge, monitoring and warning, dissemination and communication, and response capability. Risk knowledge involves collecting data and conducting risk assessments to assist relevant stakeholders to enhance knowledge about hazards, vulnerabilities and capacities in order to design early warning systems, prepare for preventive actions and guide effective response [3,7,8]. Monitoring requires hazard monitoring and early warning services from global to community levels [3]. Combining scientific knowledge with local knowledge is essential to provide accurate and reliable monitoring and predictions in order to produce useful information to authorities, relevant stakeholders, a community at risk, and the general public [7,9–11]. Dissemination and communication aims to develop a system that ensures the target people are warned in advance of impending disasters [6]. Messages can be disseminated via different channels such as social media, cellphone, radio, or television among others (sirens, megaphones etc.) [7]. Importantly, UNDRR [12] emphasized that the warning information needs to be well understood in terms of the risk, and clear and usable so that the people at risk can take appropriate action. Several important activities are required to achieve effective response capability. They include developing national and community response capability plans which are regularly tested and updated [3]. Education, training, preparedness, and risk awareness programs for all disaster management actors including communities play a significant role in improving response capability [13–15].

The EWS requires not merely a mechanism to issue the warnings but it needs strong integration between the four elements prior to a disaster occurring to achieve the most effective response [7,16]. Additionally, the UNDRR [6] and IFRC [7] reported that the EWS is a system that not only utilizes technology but also facilitates effective interaction among authorities, disaster management stakeholders and communities across the four elements of the system.

Nevertheless, much EWS design and operation still focuses on a single element, focusing heavily on technology and equipment [4,17] which can lead to failure of the whole system. The technology will be ineffective if communities do not respond to warnings appropriately [7].

Ineffective disaster responses associated with lack of integration and community engagement across all EWS elements have been reported in many previous disaster events. For example, in Hurricane Katrina in 2005, inadequate coordination and ineffective warning dissemination as well as insufficient partnership with grassroots organisations became a significant problem for the disaster response [18,19]. Also, Cyclone Nargis in Myanmar in 2008 killed 130,000 people partly due to the lack of engagement with local people concerning risk knowledge [7]. Many people disregarded the impact of the cyclone, and others did not have any idea how to prepare for such an event [20]. During the 2014 and 2016 floods and flash-floods that struck some regions in Aceh, Indonesia, many people were stranded, and deaths, injury and loss of belongings of the community were reported as residents did not have much time to prepare an effective response due to the absence of the necessary dissemination of information in advance [21,22].

Numerous studies have confirmed the importance of community engagement in the EWS to achieve the effectiveness of the system design and operation [7,23–25]. This is in line with the Sendai Framework for DRR in 2015–2030: strengthening people-centred systems to reduce risks and develop simple and low-cost EWS design and operation [26]. However, little is known regarding the implementation of CE in EWSs, and few studies have examined how CE has been utilized across the four elements of an EWS. Hence, this study presents a systematic literature review of existing community engagement in EWSs, with the objective of identifying how community engagement is incorporated across the EWS elements across settings and hazards.

2. Methods

The systematic literature review presented in this paper follows some steps of the general methodological guidelines set forth for systematic reviews. They include: question definition; searching and screening of papers against the inclusion and exclusion criteria; classifying or coding information from the selected studies, based on the screening process; and analysing the information following specific criteria and using statistical or descriptive themes [27–31].

2.1. Question definition

The systematic review was guided by the following research question: What community engagement activity is incorporated within the key elements of EWS?

2.2. Search protocol

Databases used to locate scientific papers included Scopus, Web of Science, Science Direct and Wiley online. In addition to published articles, we included documents from governments and key international agencies such as UN, UNDRR (or UNISDR as it was formally known), IFRC, and International Early Warning Conference, as well as international NGO project reports such as those of UNDP, ADPC, World Vision, Care, Oxfam, and Save the Children using Google Advanced and Google Scholar. We also explored the references of selected sources to identify further relevant published material.

The inclusion criteria included literature published in English within the publication period (2008- March 2018) that matched keyword combinations during the search process. The keywords included “Community OR Community Engagement OR Community Participation OR Community Involvement” AND “Early Warning System OR Early Warning OR Preparedness OR Risk knowledge OR Prediction OR Monitoring OR Dissemination OR Response” AND “Disasters OR Natural hazards”. Key words representing the four key elements of EWS were deliberately used to examine community engagement activity in each element of the system design and operation, which was not previously researched. Thus, the activities related to each element of the system based on search findings were reviewed.

The exclusion criteria were non-English literature, non-academic journals including Wikipedia, personal opinions such as blogs, tweets, and journals, articles or reports written by particular interest group websites. Further, studies that did not focus on case examples of describing CE in EWS for a specific hazard in a specific location were also excluded.

2.3. Screening process

Based on the following three steps of screening, 31 documents which met the inclusion criteria (16 grey literature documents and 15 peer-reviewed papers) were selected for the literature review (as shown in Fig. 1). The 16 selected grey literature documents were from government and recognized international agency reports on engaging communities in disaster risk reduction and management, disaster preparedness and EWSs. Also, the reports that defined definitions and concepts of EWSs and CE in EWSs were selected. The 15 selected peer-reviewed papers were studies on engaging communities in disaster management and preparedness focusing on any elements of EWSs, and CE in EWS within case studies.

The literature on EWS concepts, CE in EWS aspects including case study reports on CE in EWSs were included to strengthen the discussion and
understanding of definitions, concepts and the importance of early warning systems as well as the applicability of CE in EWSs. Key aspects analysed in this systematic literature review study included: general descriptions of CE in EWS based on types of hazard and country region and types of CE activity within each element of EWS. Themes common to much of the literature were identified, described and analysed to answer the research question.

3. Findings and discussion

3.1. Definitions and concepts of Early Warning Systems (EWSs) and CE in EWSs

Various definitions of EWSs have been used by different organisations. In 2006, UNDRR [32, p. 12] defined the early warning system as "a set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organisations threatened by a hazard to prepare and act appropriately and in sufficient time to reduce the possibility of harm or loss". Based on this definition, the EWS is focused mainly on the dissemination element of the system to transfer risk information to those at risk. Also, this implies that the community remains passive as they only receive warning information during an emergency from authorised agencies in order to take effective response rather than that they are actively involved in the system.

Basically, affected communities should be involved in identifying the early indicators for impending threats so that they can prepare themselves adequately. In this respect, we agree with Macherera and Chimbari [33], who define early as 'a relative term' depending on the type of disaster, those affected and capacity or available resources to cope with disaster impacts. Similarly, the Federation of Red Cross and Red Crescent Societies further indicates the word early as the condition in which disaster management actors, the community at risk and other relevant actors are able to prepare to act properly before a hazard or threat occurs since there is still time to reduce or prevent the potential negative impacts of disasters [34]. A warning is a message that can be disseminated through various forms such as words, sounds or images to announce a danger situation. Further, a system is a set of elements that interact each other in multiple directions between those who need to receive a message and those who compile and track the hazard information [34]. In the context of community engagement in EWSs, communities are defined as a group of people who share a similar location, interest, belief, and social network that may be exposed to the same hazards or threats [12, 34].

Community engagement is often interchangeably used with community participation or involvement to describe actions taken to engage with communities and interest groups in dealing with issues that affect them within five main types of engagement processes: informing, consulting, involving,
collaborating and empowering [35,36]. CE in EWS is defined as the process of involving communities to collect, assess, monitor, and disseminate hazard risk information to those at risk as well as facilitate emergency plans or responses [34]. For the purpose of this study, all five types of CE process are considered as one engagement approach and are equally important. Common CE principles in EWS drawn from various studies include the need to understand local context, embracing multiple knowledge types (transmitted, experiential and empirical knowledge), initiating partnerships with various stakeholders and utilising a multi-hazard approach [6,34,37].

Community engagement in EWS can include community-based or community-driven EWS (CB or CDEWS) in which the system can be located within a particular community without being owned or carried out by the community [34]. However, a community is required to have a strong understanding of the EWS in order to obtain the most benefit from the system’s operation. Thus, the community is required to be comprehensively engaged with the design and operation of EWS, and not only respond to warning messages at local level. According to the UNDRR (2006), effective early warning systems require better understanding on technical issues, knowledge about risks, and engaging with communities [6]. The importance of engaging the community with the system was first formally recognized in the second world conference on disaster reduction held in Kobe, Japan in 2005 [37]. The conference highlighted the following features of people-centred EWS: a bottom-up and top-down process; engaging the community in the early warning operation; and a multiple hazard approach. This extends the original definition of community engagement in EWSs such that those affected are not only warning receivers but also initiate warnings. People-centred or integrated EWS was also the main agenda in the third International Early Warning conference held in Bonn, Germany in 2006. The conference highlighted the four EWS elements including risk knowledge, monitoring and warning, dissemination and communication, and response capability [6,38], and identified that a weakness in one of these elements can lead to failure of the system. In this respect, we argue here that the community needs to be engaged across all four elements of EWS in order to achieve effective early warning design and operation. Further, the third world conference on Disaster Risk Reduction in Sendai, Japan in 2015 outlined more people-centred preventive measures to reduce risks [26]. It also emphasized that DRR practices need to engage with a wide range of stakeholders such as women, children, youth, the disabled, indigenous groups and immigrants. Likewise, the first Multi-Hazard Early Warning Conference (MHEWC) organized by the World Meteorological Organisation (WMO) in 2017: Save lives and Reduce Losses, recommended the people-centred approach through integrating grassroots organisations and local people into the meteorological, geophysical, hydrological agencies, and information technology and communication sectors as well as other key disaster management actors [39]. Similarly, the second MHEWC in 2019 put more emphasis on engaging the community in EWSs: enhancing community engagement in designing and operating MHEWSs that includes disaster risk education, training (drill or simulation) and awareness raising efforts to tailor warning messages to specific group needs [40].

3.2. Applicability of CE within EWS

According to Baudoin et al. [24], CE in EWS design and operation can be influenced by the type of hazards. Large-scale, slow environmental problems e.g. droughts can be managed through centralized systems; however, localised disaster events such as floods can be managed at the community or local level. They also argue that a community cannot be engaged with some hazards that require an advanced technology to enable the early warning system to operate accurately, for instance the detection of cyclones, earthquakes and tsunamis. However, as clearly highlighted by the IFRC, communities should be engaged in numerous disaster events with either slow or rapid onsets such as floods or flash floods, landslides, cyclones, droughts, volcanic eruptions, and epidemics [34]. This is because the community involvement in EWS varies in methods, indicators, and timescales. The system at the local level usually complements or strengthens the government EWS at district, or provincial or national levels rather than replaces them.

Community engagement in EWS should consider early actions, because an early warning has no effect without early actions. The early actions actually cover a wider range of timescales including years, months, weeks, days, and hours [41]. Thus, the community should be engaged within these timescales across four elements of EWS. For example, at the shortest timescales, the action could be evacuation. For the longest timescales, early action means involving the community to assess and address the underlying causes of the changing risks they may face e.g. planting trees to reduce landslides, disaster awareness and management campaigns, disaster exercises, drills and simulations, constructing evacuation centres and evacuation routes, stocking and preparing basic needs for disasters, and other disaster risk reduction measures. Early actions also include updated contingency planning and volunteer deployment [7].

To support the early warning, early action activities, Forecast-based Financing (FbF) scheme should be considered in the disaster management plan especially in countries that do not allocate funds for preparedness programs [42]. By doing so, the scheme can release funds for preventive and preparedness activities based on forecasts prior to the actual disaster event occurs.

3.3. CE in EWS based on various hazards and regions

Of the final set of literature that met the inclusion criteria (n = 31) documents, 16 were project reports and 15 were peer-reviewed research papers, with the highest number (n = 16) from the Asian region and 8 from the African region. A further 3 were from Oceania and North America respectively (as shown in Fig. 2). Most selected documents (n = 31) involving the community in EWS design and operation were from Low- and Middle-Income Countries (LMICs). As English is not the first language for many LMICs [43], many more CE in EWS literature or reports may have been documented in another language but were not included in this study.

The distribution of included country settings is not surprising as Asia has experienced the highest number of natural hazards in terms of frequency and magnitude, most likely due to its size and socio-economic vulnerabilities [44]. Countries in the Asian and African regions are frequently impacted by multiple hazards related to climatological, geophysical, hydrological and meteorological threats [45].

In addition, the majority of these documents (n = 24) discussed engaging communities in EWS based on a single hazard rather than general or multiple hazards (as shown in Fig. 3). They focused on engaging communities in risk reduction programs for floods, landslides droughts, cyclones and volcanic eruptions. Only 7 documents examined a case or setting within a multiple-hazard EWS.

However, involving the community in the design and operation of an EWS that utilises a multi-hazard approach is important, since it enhances system efficiency when human and financial resources are limited. For instance, one person can monitor indicators for multiple potential hazards [34], additionally, despite hazards behaving differently and affecting very different timescales and geographical areas, the design and operation of the system is very similar. For instance, the use of colour coded staged warning levels (e.g. green, yellow, red), the process of setting thresholds that trigger action, and communication instruments used to issue warnings are common to all hazard events.

3.4. Types of CE activity within EWS elements

- Community engagement across four EWS elements sourced from grey literature (project reports)

Many projects sourced from the grey literature (n = 16) reported engagement with the community and other stakeholders such as local governments, local organisations and disaster management officers across all four elements of EWS. However, six documents reported on engagement of the community which were not comprehensive across all four elements (as
show in Table 1). For example, a pilot project on the Local Level Risk Management (LLRM) for floods in Fiji engaged the community in vulnerability and capacity assessments and in evacuation drills for floods [46]. The CBEWS for volcanic eruption project in Comoros, supported by Comorian Red Crescent, engaged the community in participatory risk mapping, dissemination of risk information via satellite radio, and training for first aid and evacuation activities. However, the communities were not clearly engaged in monitoring activities [47]. The UN Habitat led project on reducing community vulnerabilities to cyclones in Mozambique involved the community in identifying low cost housing materials resistant to cyclones and in constructing their houses [48]. The Oxfam led project on droughts in South Africa engaged the community in risk assessment mapping and monitoring of food security, rainfall, and community health [49], but they were not clearly involved in dissemination and response elements. The RAD (Rapid Application Development) project led by De La Salle University in Manila engaged the community with technology within the dissemination element of EWS using social media such as Facebook, Twitter and the Internet [50]. The International Centre for Integrated Mountain Development (ICIMOD) developed CBF EWS in Assam, India in 2016 [51]. The CBF EWS was people-centred, simple and used low-cost technology. It involved the community in developing risk maps and identifying the vulnerable groups. The involved community was introduced to the flood monitoring instrument installed up and down streams. They were also involved in disseminating flood risk information from upstream to the vulnerable communities downstream through text (e.g. SMS), verbal or sound (e.g. siren, telephone, megaphone, or shouting) and visual cues (colour, flags, signs) [51]. However, the CBF EWS was identified as being heavily dependent on the installed instrument upstream to generate flood risk information; had poor quality of telecommunication systems and technology; inadequate involvement of all vulnerable groups in the design and operation of the instrument such as women, low income groups, the disabled, the illiterate, and the elderly; and lack of integration of indigenous or local knowledge into the system [51].

- Community engagement across four EWS elements sourced from peer-reviewed papers

Of the 15 selected peer-reviewed research papers that met the inclusion criteria, most reported community engagement (14 research papers), but not explicitly across all the four elements of EWSs. For example, Gonzales et al. [52] designed a CBEWS in Leveriza, Manila. The community was engaged with using technology such as handphones and the Internet. The system focused on the dissemination element using some features such as short message services (SMSs), webpages, and Google Maps. Chandra et al. [53] established a table top exercise through the Los Angeles County Disaster Resilience (LACCDR) program. It aimed to increase community resilience to heatwaves in Los Angeles, through involving the community and other stakeholders such as government officers, disaster response staff and volunteers. The exercise mainly involved stakeholders in the response element of EWS. Similarly, Flint and Stevenson [54] reported that the local community in the state of Illinois was involved in emergency responses (e.g. fire safety, disaster medical operations, search and rescue operations, simulations and drills) through the CERT program. Paul [55] reported
and dissemination elements. Liu et al. [58] designed a community-based di-
Thus, the CBFEWS program involved the community across monitoring,
ing stations using communication tools such as satellites and handy talkies.
formation description pictures) were sent to local governments using cell
ners and smart phones to monitor landslides. The monitoring data (land de-
China. The local community was trained to use steel piles, convergence me-
Flood forecasting branch. It aimed to increase local community capacities
implemented by the Local Government Unit (LGU) and supported by the
in receiving and disseminating risk information between community and
authorities in order to enhance
in the 2007 cyclone Sidr, the majority of local communities were re-
dissemination of cyclone warnings using megaphones, handheld bullhorns,
bicycle-mounted loudspeakers, and through house-to-house contact. How-
erver, in the 2007 cyclone Sidr, the majority of local communities were re-
Early actions (as
needs of communities for cyclone preparedness including the appropriate
activities in
od EWS among farmers in Kaijuri Union, Bangladesh. The
farmers were involved in drawing flood risk maps. They used their local
knowledge to predict rainfall by observing wind direction and clouds, and
they usually received flood risk information via radio and television. Perez [57] described a CBFEWS program (supported by the PAGASA) to re-
duce flood risks to communities in Bulacan, Philippines. The program was
implemented by the Local Government Unit (LGU) and supported by the
Flood forecasting branch. It aimed to increase local community capacities
in receiving and disseminating risk information between community and
authorities in order to enhance flood resilience. The local community was
trained by LGU officers and local NGOs to monitor water levels at monitoring
stations using communication tools such as satellites and handy talkies.
Thus, the CBFEWS program involved the community across monitoring,
and dissemination elements. Liu et al. [58] designed a community-based di-
saster risk reduction, a CBDRR program (supported by the local govern-
ment) to enhance community resilience to landslides in Wanzhou district,
China. The local community was trained to use steel piles, convergence me-
ters and smart phones to monitor landslides. The monitoring data (land de-
formation description pictures) were sent to local governments using cell
phones. The framework engaged the local community via the monitoring
and dissemination elements.
Further, the other examples of CE activities in the risk knowledge ele-
ment were reported from the other four peer-reviewed papers. For example,
community engagement in risk assessment and adaptation strategies
through community participation to reduce their vulnerabilities to coastal
hazards in Matlab, Bangladesh [59]. In this research the SMUG (Serious-
ness, Manageability, Urgency and Growth) model and the FEMA (United
States Federal Emergency Management) model using four scoring systems
of hazards (history, vulnerability, maximum threat and probability) were
used to analyse the community risk and adaptation strategies, engaging
the local community in the risk knowledge element of EWS. Also, Daly et al.
[60] described community participation in the Coastal Infrastructure
Management Project (CIMP) to reduce Samoa’s coastal infrastructure vul-
nerenabilities. The local community was involved in drawing risk and hazard
maps during a village consultation. Similarly, Haworth [61] presented com-
munity engagement in hazard mappings for bushfires in Tasmania,
Australia, through the Volunteered Geographic Information (VGI) program
created by private citizens. The involved community identified the
strengths and weaknesses with manual or paper mapping and digital map-
pings. However, the community was not noticeably engaged in monitoring,
dissemination and response elements reported in this research paper.
Furthermore, research by Reichel and Frömming [62] presented community
engagement through participatory (GIS) mapping on hazard risks (orga-
nized by the local government) using cartographic papers combined with
multimedia mapping to reduce climate-related risks in the Alpine region
of Switzerland.

The other community engagement activities in EWSs were presented in
another peer-reviewed paper by Baudoin et al. [24] in three case studies in
Sri Lanka, Kenya and Hawaii. None of these case studies engaged the

Table 1
Summary of selected documents on engaging the community within different elements of EWSs (n = 31).

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Research site</th>
<th>Hazard</th>
<th>Focus on EWS elements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Risk knowledge</td>
<td>Monitoring</td>
</tr>
<tr>
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<td>Samoa</td>
<td>Coastal hazards</td>
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</tr>
<tr>
<td>Islam, M.N., Malak, M.A.</td>
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<td>Bangladesh</td>
<td>Coastal hazards</td>
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</tr>
<tr>
<td>Chandra et al.</td>
<td>2015</td>
<td>USA</td>
<td>Heatwaves</td>
<td>✓</td>
</tr>
<tr>
<td>Flint, C.G., Stevenson, J.</td>
<td>2010</td>
<td>USA</td>
<td>General hazards</td>
<td>✓</td>
</tr>
<tr>
<td>Paul, B.K.</td>
<td>2012</td>
<td>Bangladesh</td>
<td>Cyclones</td>
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</tr>
<tr>
<td>De La Salle University Manila</td>
<td>2012</td>
<td>Philippines</td>
<td>General hazards</td>
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</tr>
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</tr>
<tr>
<td></td>
<td></td>
<td>Sri Lanka</td>
<td>Landslides</td>
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<td></td>
<td></td>
<td>Hawai’i</td>
<td>Coastal hazards</td>
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<td>Mustafa et al.</td>
<td>2015</td>
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<td>Floods</td>
<td>✓</td>
</tr>
<tr>
<td>Ardalan et al.</td>
<td>2009</td>
<td>Iran</td>
<td>Flash floods</td>
<td>✓</td>
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<td>Perez, R.T.</td>
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<td>Oxfam</td>
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<td>Droughts</td>
<td>✓</td>
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<td>UNDP Pacific centre</td>
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<td>Floods</td>
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<td>Asian Disaster Preparedness Centre (ADPC)</td>
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<tr>
<td>World Vision</td>
<td>2015</td>
<td>South Africa</td>
<td>Floods and landslides</td>
<td>✓</td>
</tr>
<tr>
<td>Centre for International Studies and Cooperation (CECI)</td>
<td>2011</td>
<td>Vietnam</td>
<td>Floods</td>
<td>✓</td>
</tr>
<tr>
<td>Christian Aid</td>
<td>2010</td>
<td>Malawi</td>
<td>Floods</td>
<td>✓</td>
</tr>
<tr>
<td>CARE</td>
<td>2010</td>
<td>Madagascar</td>
<td>Cyclones</td>
<td>✓</td>
</tr>
<tr>
<td>Oxfam</td>
<td>2008</td>
<td>Java, Indonesia</td>
<td>Volcanic eruptions</td>
<td>✓</td>
</tr>
<tr>
<td>ADCP &amp; PROMISE</td>
<td>2011</td>
<td>Jakarta, Indonesia</td>
<td>Floods</td>
<td>✓</td>
</tr>
<tr>
<td>Cruz Vermelha de Moçambique (CVM)</td>
<td>2008</td>
<td>Mozambique</td>
<td>Floods</td>
<td>✓</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>22</td>
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</tbody>
</table>

That local communities in coastal areas in Bangladesh were involved in the dissemination of cyclone warnings using megaphones, handheld bullhorns, bicycle-mounted loudspeakers, and through house-to-house contact. However, in the 2007 cyclone Sidr, the majority of local communities were reluctant to evacuate to shelters because the evacuation shelters were far from their areas, the local communities especially the elderly and the illiterate did not trust to the warnings [55]. In this respect, engaging all vulnerable groups across the four EWS elements through early actions (as mentioned in Section 3.2) can enhance community trust and assess the needs of communities for cyclone preparedness including the appropriate construction of shelter sites. Further, Fakhruddin et al. [56] reported CE activities in flood EWS among farmers in Kajjuri Union, Bangladesh. The farmers were involved in drawing flood risk maps. They used their local knowledge to predict rainfall by observing wind direction and clouds, and they usually received flood risk information via radio and television. Perez [57] described a CBFEWS program (supported by the PAGASA) to reduce flood risks to communities in Bulacan, Philippines. The program was implemented by the Local Government Unit (LGU) and supported by the Flood forecasting branch. It aimed to increase local community capacities in receiving and disseminating risk information between community and authorities in order to enhance flood resilience. The local community was trained by LGU officers and local NGOs to monitor water levels at monitoring stations using communication tools such as satellites and handy talkies. Thus, the CBFEWS program involved the community across monitoring, and dissemination elements. Liu et al. [58] designed a community-based disaster risk reduction, a CBDRR program (supported by the local government) to enhance community resilience to landslides in Wanzhou district, China. The local community was trained to use steel piles, convergence meters and smart phones to monitor landslides. The monitoring data (land deformation description pictures) were sent to local governments using cell
community within all four elements of the EWSs. For example, in the first case study on landslide risk mitigation funded by UNDP in Matale district, Sri Lanka, communities were engaged in risk detection for flooding using simple fiberglass rain gauges. Also, the community was involved in education programs and training on Search and Rescue activities, and evacuation drills for floods [63]. In the second case study report on floods in Kenya (supported by Kenyan DRR initiative), the local community was most engaged in the dissemination element [24]. For example, urban communities in Nairobi were engaged in receiving and sending disaster risk information using various channels such as mobile phones, the internet, radio and TV. In rural locations, communities received and sent information via radio and mobile phone. The third case study, implemented by Disaster Resilience Committees to reduce tsunami and flashfloods in Hawai‘i, involved communities in both the risk knowledge and response elements. For example, the community was engaged in participatory hazard and risk mappings using a GIS system and paper-based mapping. The community was also engaged in training activities to stock food and water supplies, provide social support and access safe spaces for evacuation. In addition, the other case study conducted by Mustafa et al. [64] in Pakistan reported a lack of gender involvement especially women in the four elements of flood EWSs in Lai Basin rivers. This research highlights the importance of local governments, disaster management actors, respected or religious leaders and other relevant stakeholders to consider the involvement of women in EWS design and operation in order to reduce their vulnerability to floods. Female participants of FGDs in this case study commented that only some women under their own initiative monitor the water levels in rivers. However, they were not able to understand official warning messages from the government due to the language barrier or respond to warning messages directly because they needed to obtain permission from males/their husbands. The flood EWS was also reported as a techno-centric EWS operation with lack of integration of multiple knowledge types into the system. Furthermore, Ardalan et al. [65] reported another case study concerning inadequate engagement of the community in EWS for flash-floods in Golestan province, Iran. Some communities at provincial level were involved in monitoring rainfall and river water levels through the use of automatic rain gauge technology at rain gauge stations. However, there was a failure to explore whether local knowledge could be integrated into the technology. Also, although most people at provincial and rural locations were aware of their risk to flooding, the local people especially at village level were not familiar with the existence of flood risk maps, were not routinely engaged with flood drills. They normally received flood risk information from the Provincial Meteorological Office following top-down fashion via radio or television.

Interestingly, only one of the 15 peer-reviewed research papers [66] outlined engaging communities throughout all four elements of EWSs. The paper examined the applicability and effectiveness of engaging the community with an early warning system for disaster management actors, respected or religious leaders and other relevant agencies through their policies, regulations, planning and program implementation is critical to effective disaster management and ensure the continuity of the projects. In addition, in the findings identified from 31 documents, the CE activities across the four EWS elements were dominated by project reports (as shown in Fig. 4). Communities were mainly engaged in the risk knowledge element (n = 22) in both types of document (i.e. peer-reviewed papers and grey literature from project reports), followed by monitoring, and dissemination and communication elements (n = 19 respectively), as well as the response element of the system (n = 18).

Table 2 shows the most common CE activities across the four EWS elements. In the risk knowledge element, communities were routinely engaged in manual drawing of risk and hazard maps on simple or cartographic papers or boards. They also participated in hazard mapping with a combination of paper and digital based maps. However, understanding the characteristics of risk is crucial since risk is dynamic and ever-changing in the process of interaction between hazard and vulnerability conditions [50]. Thus, a continual process to understand the changing nature of both hazards and vulnerabilities is important to risk knowledge assessment and should not end with the effort to produce risk and hazard maps. Within the monitoring element, communities were engaged in using rain gauges, both upstream and downstream, to monitor floods and landslides. Also, they were involved in monitoring human health, especially of old people and children, during droughts. Beyond these physical monitoring activities, combining traditional/indigenous methods with scientific knowledge within the community needs to be better explored and integrated into EWS design and operation. For example, in Mozambique, downstream communities monitor the colour of river water and type of debris floating down to justify the scale of a potential flood that will likely occur [68]. This traditional knowledge is very useful in remote areas which do not have access to meteorological methods of forecasting. Thus, it could be considered for other similar rural communities. Further, for different slow onset hazards such as droughts, community monitoring is critical to prepare for effective response [7]. For these types of hazard, the affected communities should be able to recognise the signs of drought (e.g. food and clean water shortages, or some diseases associated with droughts) earlier than the authorities.

The majority of urban communities were usually engaged in the dissemination and communication element using advanced information and communication technologies (ICTs) which are easily available on the cities to enhance one and two-way communication processes. For example, two-way communication processes occurred between some community groups (registered, trained, or subscribers to the system) and authorities. These groups used ICTs such as mobile phones, Facebook, Google maps and Twitter to disseminate and receive warning messages. These two-way communication processes usually occur immediately before a disaster to identify readiness to take appropriate action and during emergency relief efforts to assess need and provide assistance. Other community groups, especially those living in remote locations, received risk information via radio, or television (one-way communication). However, other vulnerable groups in such locations e.g. the disabled, illiterate or old people may not receive information via electronic media. Thus, the information needs to be passed to these groups using traditional communication tools such as hand operated sirens, loudspeakers, drums, whistles, coloured flags or house to house visits [34,69]. Bridging two-way communication flows between two groups...
(urban-rural communities) and authorities is essential to achieve an effective warning dissemination process [70]. In this context, the role of social networks and traditional institutions and systems (for example, key leaders, or respected persons) in remote areas can be critical to maintaining the top-down and bottom-up information flows.

In the response element, communities were often involved in disaster evacuation drills, search and rescue exercises, first aid care training, and the preparation of food and other basic needs for emergency situations [54,62].

Such activities usually facilitate the engagement of the community to prepare for response to emergency conditions. However, community engagement in EWSs ought to be active not only in an emergency, but also during normal conditions, as it allows communities to observe the benefits of the system design and operation and are able to participate in collecting, analysing and disseminating the information, as well as seeking their feedback for improvement [7,68].

3.6. Challenges and gaps for CE in EWSs

Review findings identified numerous challenges to engaging the community in EWSs. They included inadequate sustainability of engaging the community in EWS design and operation due to insufficiency of funds, technical assistance and human resources (experts) when supported agencies terminate their projects [64,71]. This reinforces the view that work needs to be done to incorporate such actions into formal institutional and legal frameworks as government policy in order to continue to improve EWSs and hence disaster preparedness [71]. In this respect, the political will of local governments and other stakeholders including the community to continue improving the system is essential.

The other challenge to the sustainability of engaging the community cited by project implementers is inadequate Standard Operation Procedures (SOPs) for the process of implementing CE in EWSs. Based on the findings, only the Mercy Corp and the Practical Action have comprehensive and simple guidelines for CE in EWS projects. Thus, it is important to develop standard guidelines for engaging the community in EWS project implementation. FARM Africa’s manual guidelines on establishing community managed DRR in South Omo pastoral areas provide a comprehensive, well-structured model of engaging the community in EWS projects [72].

Most community engagement activities identified in the findings were not readily identified as being linked/integrated into the government EWS. The government EWS is often standalone, with the activities at community level not connected or channelled to the government system. This is similar to what has been reported by Shrestha et al. [73] in Nepal, where even though a majority of organisations engaged the community in response capacity building activities, these activities were not systematic and generally not directly linked to the formal EWS. According to IFRC [34], ideal CE activities need to be supported by district or provincial or even national early warning systems since the community may not have adequate resources to respond to all disaster types within their locality. In this situation, the community can inform the government authorities in order to obtain assistance. Therefore, all CE activities within all the four EWS elements need to be better integrated with formal government EWSs so that authorities or other involved actors including the community understand their roles and responsibilities within the system and are more motivated to ensure community engagement is resourced and sustained.

The absence of integration of indigenous or traditional knowledge with scientific knowledge across all four elements is another challenge for engaging the community in EWSs within reported studies. As mentioned by Tran et al. [74], the effectiveness of CE in EWS design and operation needs to embrace multiple knowledge types including transferred, experiential and scientific or empirical knowledge in order to ensure the effectiveness of the system.

Table 2

<table>
<thead>
<tr>
<th>CE activities in EWS Elements</th>
<th>Risk knowledge</th>
<th>Monitoring</th>
<th>Dissemination and communication</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community involved in drawing risk and hazard maps and combination with digital mapping</td>
<td>Community trained to use steel piles, convergence meters and smart phones to monitor landslides, Community involved in monitoring rainfall using fibre glass rain gauges and floods using upstream and downstream painted gauges, Community involved in monitoring animal health, human health (malnourishment), rainfall, and crop pests.</td>
<td>Two-way communication between trained community, subscribers, registered communities and authorities using ICTs such as smartphones, internet, wireless radio, Google maps, SMS, Twitter, or Facebook, One-way dissemination using electronic media such as radio or TV.</td>
<td>Experts and communities involved in top table exercise, Community involved in evacuation drills, Community trained in stocking food and planting crops according to season, Community trained in first aid care, and basic life support.</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4. Document sources focusing on CE in different elements of EWSs (n = 31).
Another important challenge is lack of involvement of all vulnerable groups within the design and operation of EWSs. As pointed out by Kafle [75], CE in EWSs requires four essential aspects: effectiveness, efficiency, equity and legitimacy. Thus, the system should be useable for the disabled and the elderly, and able to address the needs of all vulnerable groups at the local level. Further, inadequate gender involvement, especially of women, across the four elements of EWS leads to greater vulnerability of this group to disaster events in many countries. The study conducted by Shrestha et al. [73], published by ICIMOD in Nepal in 2014 observed that none of the organisations conducted comprehensive hazard and vulnerability assessments with adequate emphasis on traditional knowledge of women and their perceptions. Only four of nine organisations that were involved in flood monitoring and warning services engaged with women to monitor hazard risks. Dissemination flood warning information via radio and mobile phone did not ensure the messages were received by women. Even though some organisations had established women’s groups and involved women and girls in EWSs, the messages and dissemination methods were not gender sensitive. Although women play a significant role in disaster responses and are able to manage, adapt, and withstand the impact of disasters, they are not commonly engaged in the EWS response processes.

To address the current identified challenges and gaps for engaging the community in EWSs, key areas for further research include: how to better resource and sustain CE in EWSs; better understanding of different sectors of the community and their engagement needs (vulnerable people); and feasibility of emerging ICTs in different settings to improve the monitoring and dissemination and communication elements of EWSs.

4. Limitations

Some limitations of this study may affect the validity of the findings. They include the absence of other examples and insights into CE activity information from studies that were excluded, such as older studies or those not reported in English. Also, as a large number of included studies were from grey literature which is not necessarily subject to peer-review, the quality of these reports is not well established.

5. Conclusion

This study has reviewed the definitions and concepts of EWSs, as well as the importance of CE in EWSs and its applicability which has been emphasized in many acknowledged international organisation agendas such as UNDRR, IFRC and WMO and strengthened since its initial identification in 2006 by UNDRR.

Based on the screening process of the 4211 total document records, 31 documents that met the inclusion criteria were selected for review. 16 documents were grey literature from project reports and the other 15 were peer-reviewed papers. The key aspects of general descriptions of CE in EWSs according to types of hazard and country region, and types of CE activity across the four EWS elements were analysed in the 31 selected documents.

The findings identified that most documents were from developing countries (Asia and Africa) which reported on engaging the community in the design and operation of EWSs focusing on a single hazard such as flood, landslide, drought, cyclone, and volcanic eruption. Additionally, communities were inadequately engaged across all four elements of EWSs, with the risk knowledge element of the system being the most commonly reported CE activity. Urban populations were usually engaged in the dissemination and communication element using advanced ICTs (e.g. mobile phones Facebook, Twitter, and google maps etc.) to maintain a two-way communication to disseminate or communicate warning information.

Various key challenges and gaps for engaging the community in the design and operation of EWSs have been identified. For example, sustainability of CE in EWSs is challenging due to inadequate technical, financial and human resources when support agencies (NGOs) finish their projects. Related to this, a common issue is a lack of SOPs for engaging the community in EWSs, as well as a lack of linkage between CE activities and the formal government EWS. Further, the findings indicated that there was inadequate integration of local or indigenous and scientific knowledge into EWSs, and all vulnerable groups are not routinely engaged in the system.

Future work relating to CE in EWSs should have greater focus on planned systematic and comprehensive engagement of the community across the four elements of EWSs with consideration of multi-hazard approach and the four principles of engaging the community in the system [7, 24,34], and a more in-depth exploration of the potential enabling factors and barriers to engaging with the community in EWSs. It is also important to support traditional respected leaders (religious or local key figures) at the community level can improve their community participation in disaster risk reduction efforts including the design and operation of EWSs in order to enhance the effectiveness of the system [76, 77]. In addition to that, central and local governments as policy makers need to formalise CE in EWSs within short and long-term Disaster Management Plans.

Declaration of competing interest

None.

References

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