Int J Disaster Risk Sci (2016) 7:163–174
DOI 10.1007/s13753-016-0085-6

CrossMark
www.ijdrs.com
www.springer.com/13753

ARTICLE

From Top-Down to "Community-Centric" Approaches to Early Warning Systems: Exploring Pathways to Improve Disaster Risk Reduction Through Community Participation

Marie-Ange Baudoin[1,2] · Sarah Henly-Shepard[3] · Nishara Fernando[4] · Asha Sitati[5] · Zinta Zommers[5]

Published online: 9 May 2016

Abstract Natural hazards and their related impacts can have powerful implications for humanity, particularly communities with deep reliance on natural resources. The development of effective early warning systems (EWS) can contribute to reducing natural hazard impacts on communities by improving risk reduction strategies and activities. However, current shortcomings in the conception and applications of EWS undermine risk reduction at the grassroots level. This article explores various pathways to involve local communities in EWS from top-down to more participatory approaches. Based on a literature review and three case studies that outline various levels of participation in EWS in Kenya, Hawai'i, and Sri Lanka, the article suggests a need to review the way EWS are designed and applied, promoting a shift from the traditional expert-driven approach to one that is embedded at the grassroots level and driven by the vulnerable communities. Such a community-centric approach also raises multiple challenges linked to a necessary shift of conception of EWS and highlights the need for more research on pathways for sustainable community engagement.

✉ Marie-Ange Baudoin
marieange007@gmail.com

1 African Climate and Development Initiative, University of Cape Town, Rondebosch 7701, South Africa

2 Consortium for Capacity Building, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO 80309, USA

3 Disaster Resilience L.L.C., Honolulu, HI 96822, USA

4 Department of Sociology, University of Colombo, Colombo, Sri Lanka

5 Division of Early Warning and Assessment, United Nation Environment Programme, Nairobi, Kenya

Keywords Early warning system · Hawai'i · Kenya · Natural hazards · Participatory approach · Risk preparedness · Sri Lanka

1 Introduction

For several decades, international organizations, together with developed and developing nations, have sought ways to reduce hazard impacts on society, developing risk reduction and management plans, designing and implementing early warning systems, and/or raising risk awareness from the local to international levels. This is reflected in the adoption of the 1994 Yokohama Strategy (UN 1994) and the Sendai Framework for Disaster Risk Reduction 2015–2030 adopted in 2015 (UNISDR 2015). Yet, the impacts of natural hazards on society are increasing in incidence and severity in terms of economic costs and loss of life, a trend likely to continue due to increased vulnerability linked to population growth, rapid urbanization, and other unsustainable development trends (Basher 2006; IPCC 2012, 2013; World Bank 2013; Guha-Sapir et al. 2014).

A high degree of vulnerability to natural hazards is often pointed out amongst the poorest households and those located in remote areas across the world and, especially, in the global South (Hellmuth et al. 2007; Leary et al. 2008; Guha-Sapir et al. 2014). But wealthier households are also at risk, especially in areas vulnerable to hazards because of their location, including coastal zones and small islands like Hawai'i (IPCC 2013). Societies dependent on natural resources for their livelihood, like farming communities in the Sahel, are also more affected by disruptive shifts in ecological dynamics and climate patterns. Drought or changes in rainfall seasonality affect livelihood conditions and strongly impact capacities to sustain life (Baudoin et al. 2014; Nicholson 2014).

Early warning systems (EWS) present an opportunity to reduce the impacts of natural hazards on vulnerable communities (Glantz and Baudoin 2014). But to be successful, there can be no breakdown in the processes and links that compose an effective EWS, from the risk detection stage to the emergency management stage (Basher 2006; Hall 2007; Kelman and Glantz 2014). Existing research has pointed out multiple weaknesses in EWS. Archer (2003) and Baudoin and Wolde-Georgis (2015) note that communication gaps are frequent and often result in significantly reduced coping and response capacities among the most vulnerable groups affected by natural hazards.

A possible pathway to address these gaps, according to the literature, is through enhanced community participation (Basher 2006; Maguire and Hagan 2007; Villagran de Leon et al. 2007; Mercer et al. 2009). Participatory or "community-centric" EWS (CCEWS) can be defined as initiatives by a community to collect information for hazard risk detection, to enable the dissemination of warning messages among at-risk groups, and to facilitate the implementation of emergency plans or responses that can help the community reduce harm or loss from a hazard event (IFRC 2012). Several studies have looked at possible pathways to facilitate or enhance local community participation in the design and implementation of EWS. Udu-gama (2009) underlines how using appropriate communication channels to disseminate warnings that are accessible and relevant to community members can contribute to increasing the engagement of the beneficiaries. Kelman and Glantz (2014) highlight the role of education for risk preparedness as a way to equip local people with the capacity and tools to detect and respond to natural hazards, and to truly own the risk reduction process.

This article contributes to the existing literature on participatory EWS by looking at pathways for relevant community engagement and moves beyond existing approaches by questioning the current conception of EWS as tools for risk detection and warning issuance. Based on a review of recent key publications on EWS and three case studies that illustrate attempts to set up EWS in Kenya, Hawai'i, and Sri Lanka, this article offers an overview of the values of and challenges to designing and implementing participatory EWS in the context of natural hazards. In the first section, we define and critically analyze EWS, both in their expert-driven and traditional (non-technology-based) forms. The second section presents results from the three case studies that illustrate different levels of community involvement in EWS as well as the challenges and values of a participatory process. In the third section, we compare and discuss the results from the case studies in light of the literature review to identify pathways for increased community involvement in EWS.

The conclusion recognizes the critical role of EWS for disaster risk reduction (DRR), but questions the current approach to setting up EWS, even in participatory form. We suggest that community-centric systems require rethinking the way EWS are designed and implemented, shifting from a science or expert-driven linear tool for risk detection and warning dissemination to a societal process where the vulnerable communities take the lead. This could be a pathway to ensuring the establishment of sustainable, locally relevant EWS. How to promote or facilitate community engagement remains an important field for research.

2 Research Context and Methods

This section introduces the concept of EWS, focusing on their purpose, conception, and implementation. Both modern and traditional approaches to EWS are briefly reviewed. Weaknesses in existing systems and opportunities for improvement through participatory approaches (for example, CCEWS) are then presented. Finally, the section describes the research methods used in this study and provides background information to the three case studies that are explored to analyze EWS: Kenya, Hawai'i, and Sri Lanka.

2.1 Natural Hazards, Disasters, and Early Warning Systems

Disasters are the result of intense or disruptive events, combined with society's vulnerability and level of capacity to cope with, or respond to hazards (Blaikie et al. 1994). In addition to seriously disrupting livelihoods and economic activities, disasters are significant burdens that hinder progress in many regions of the world. In Africa, disasters linked to natural hazards such as droughts and floods, for example, have significantly slowed down development and economic gains (World Bank 2012).

The notion of "natural disasters" is often used to describe the impacts of natural hazards on societies, but fails to consider the human capacity to understand risks and reduce their impacts (Basher 2006). Challenging this vision, studies in social science have put forth the concepts of vulnerability and capacity (Blaikie et al. 1994; Gaillard 2010). Similarly, research has demonstrated that the rising trend in casualties from disasters over the last 40 years is related to population growth, increased settlements in dangerous areas, environmental degradation, rapid urbanization, and other societal developments that have increased society's vulnerability to natural hazards (Basher 2006; Villagran de Leon et al. 2007; UNECA 2011).

There are various definitions of EWS in the grey (UNISDR 2009; IFRC 2012) and scientific literature (Sorensen 2000; Basher 2006). Most point out EWS' role to detect certain risks, give information to those at risk and enable them to act in order to reduce potential harm. In practice, EWS can be centralized (in the hands of a national-type agency) or decentralized (in the hands of municipal or other local agencies) (Villagran de Leon et al. 2007), depending on the type of hazards they are set up for. Early warning systems are commonly conceived as a linear chain from the risk diagnosis to the dissemination of alerts to vulnerable groups. This chain is often referred to as the "End-to-End" (or E-2-E) model (Basher 2006; UNISDR 2009) and includes four main components or links: (1) risk knowledge; (2) risk monitoring and warning services; (3) risk dissemination and communication; and (4) response capability (Basher 2006; Villagran de Leon et al. 2007). The process of setting up such a chain involves to various degrees (sometimes not at all) the beneficiaries of the EWS.

The traditional conception of EWS endorses a strong focus on risk detection and monitoring (Basher 2006). This means that EWS are often managed by regional or national meteorological or geological services in charge of risk prediction (through collecting and monitoring data) and warning issuance (to relevant authorities). This one-way process (E-2-E) does not directly engage with decision makers and beneficiaries, who are depicted as the recipients of early warnings (Glantz and Baudoin 2014; Baudoin and Wolde-Georgis 2015). In that sense, the strong links of the E-2-E chain are technological in nature (risk detection and monitoring) whereas the "societal components" of the chain (communication and response capability) are the weak links.

There are other types of traditional and less formal early warnings implemented across the world (Mercer et al. 2009). Observations of natural climate and weather patterns have been used to predict the occurrence of natural hazards for centuries and are still often used in the most remote areas of the world that are beyond the reach of technology (Basher 2006; Maguire and Hagan 2007). During the 2004 tsunami in the Indian Ocean, thousands of lives were saved in Indonesia thanks to the Simeulue (an island 150 km off the northwest coast of Sumatra) community, whose leaders were able to forecast a tsunami risk based on observations of sea behavior and reactions of buffaloes ahead of the event (Villagran de Leon et al. 2007). Local knowledge can also use bio-indicators for climate-related hazard prediction, including animal and insect behavior and plant phenology (Zommers 2014). Such systems are more flexible in practice and strongly rooted at the local level with a high reliance on community engagement. Hazard prediction techniques and emergency management are remembered through stories exchanged within the indigenous population (Mercer et al. 2009).

2.2 Strengths, Weaknesses, and Opportunities for Improvement

Whether traditional or technology-based, "EWS are only as good as their weakest link. They can, and frequently do, fail for a number of reasons" (Maskrey 1997, p. 22). Science-based systems are affected by shortcomings in risk prediction techniques, especially for hazards like tsunami (Sorensen 2000). Nevertheless, advances in technology have increased overall accuracy in risk prediction, especially for hydrometeorological hazards such as floods and hurricanes, and are in constant progress (Hellmuth et al. 2007; Baudoin and Wolde-Georgis 2015). However, natural hazards continue to severely affect communities and societies across the world (Clark 2012; Bailey 2013). While material damages cannot always be avoided, in some cases loss of human life could have been reduced if proper measures had been taken (Villagran de Leon et al. 2007).

Mercer et al. (2009) underline that no matter how specific the science behind hazard prediction is, it is not sufficient to ensure the mitigation of hazard impacts. Though accurate diagnoses are an important basis for formulating and disseminating relevant warnings, EWS include other fundamental links, such as communication and response capability. Failure to communicate in time through adequate media often leads to disastrous impacts on exposed communities (Villagran de Leon et al. 2007). Response capability also does not only rely on warning dissemination but includes training and risk awareness among vulnerable groups. It is very important that risk warnings are accessed, interpreted, and understood by different vulnerable groups across the world to be able to initiate effective and timely responses following warning issuance (Sorensen 2000; Holloway and Roomaney 2008; Glantz 2009; Mercer et al. 2009; Shah et al. 2012). Furthermore, some individuals may not have the capacity to act, even when warnings are clearly understood, and thus need further assistance (Lallau 2008).

"Traditional" (not technology-centered) EWS are also challenged in the context of global changes. Environmental degradation, population growth, urbanization, and climate change impacts can significantly alter observations of the direct environment in order to predict natural hazards. The erosion of traditional knowledge for risk management due to migrations and urbanization is already observable around the world, and bio-indicators are becoming increasingly unreliable due to climate change (Zommers 2014). Accuracy in hazard detection may require combining local observations with relevant technologies (for example, satellite observation for cyclones) as a way to augment the effectiveness of EWS (Hall 2007).

Udu-Gama (2009) and Glantz and Baudoin (2014) underline the necessity to ensure effective communication of risks through the use of media tailored to the beneficiaries. Training and education about the meanings of warnings are necessary to raise people's awareness of their existence and the role of various systems (Villagran de Leon et al. 2007). Suggestions for improvement go beyond the traditional links of EWS as Villagran de Leon et al. (2007) and Kelman and Glantz (2014) suggest the inclusion of education as part of EWS. Villagran de Leon et al. (2007) illustrate this point with the case of a little girl near Phuket, Thailand, who managed to save lives by detecting early signs of the 2004 tsunami based on the turbulent sea and loud waves. She had just learned about tsunami at school. In this view, EWS are conceived as more than alert systems that are activated once hazards are detected, but as a process that includes prehazard components such as risk education.

2.3 Community-Centric Early Warning Systems

Community-centric early warning systems (CCEWS) are promoted as a response to the gaps in the E-2-E EWS approach (that is, the weak communication links) and a way to ensure sustainability and effectiveness of disaster risk reduction (DRR). It is a system initiated and driven by its beneficiaries, thus strongly rooted at the local level. Its core principle is that vulnerable communities are driving and controlling the whole early warning process. This approach can be related to participatory methods often promoted in development and DRR programs to design projects that are locally relevant, sustainable, and that empower local people (Hickey and Mohan 2004; Chambers 2008; Mercer et al. 2009; Tozier de la Poterie and Baudoin 2015). There is no single approach to designing and implementing CCEWS. However, common principles can be drawn from recent literature on participatory methods. These principles include the need to understand local context, integrate local knowledge, and take account of individual motivations when planning and implementing risk management activities (Roncoli et al. 2008; Carr 2014; Carr and Owusu-Daaku 2016). These principles and approaches rely on an expanded commitment and involvement of those at risk (Hall 2007).

The literature on CCEWS is still young, but several arguments in favor of participative EWS stand out. One is the fact that communities already possess resilient properties when facing natural hazards, including resistance and creativity (called "social resilience") (Maguire and Hagan 2007) that can serve as a basis for EWS. According to Kelman and Glantz (2014), existing social resilience can be enhanced by informing vulnerable populations about potential changes in threats and response options. This can be achieved through risk education, hazard detection, and response plans, combining science and technology with local knowledge and experience of emergency situations and responses.

Placing communities in control of their EWS would also favor a strong engagement and empower them (Hall 2007). Long-term community engagement is especially critical in vulnerable, remote areas that can hardly be reached by warnings or emergency services (Villagran de Leon et al. 2007). In such cases, it is critical to equip local people with coping mechanisms for short-term risk mitigation (for example, tsunami warnings can facilitate risk communication and effective evacuation to save lives) and long-term anticipation through early identification of hazards (for example, early signs of drought can be detected to foster preparation through food supply and storage).

Another point raised by several authors is that participatory approaches help in considering the specific needs of a community by encouraging those at risk to take the lead in the planning, conceptualization, and application of EWS (Glantz and Baudoin 2014; Kelman and Glantz 2014). Involvement of local actors right from the beginning will not only ensure warnings that are contextually appropriate, tailored to community needs (that is, warnings are received and understood by all, using adequate media and comprehensible language), but will also ensure that EWS match local needs.

Finally, it is argued that participatory approaches are great opportunities for knowledge exchange between vulnerable groups and the scientific community (Kelman and Glantz 2014). Communities around the world use various sources of information to develop their own warning systems (Maguire and Hagan 2007) and often have an extensive knowledge of their own vulnerabilities and personal, often long-term, experience in managing risks (Tozier de la Poterie and Baudoin 2015). Local knowledge provides a wealth of locally relevant indicators for natural hazards. Coupled with science and technology, this knowledge can contribute to augmenting and confirming risk prediction (Hall 2007; Kelman and Glantz 2014), as well as to building trust among local communities, scientists, and practitioners through the way local knowledge is valued (Archer 2003; Baudoin et al. 2014).

2.4 Methodology

This study explores pathways to engaging local communities in the design and implementation of EWS and is grounded in a combination of scientific and grey literature reviews and empirical data analysis from three case studies. This approach revealed existing knowledge and gaps in the area of EWS, from their theoretical conceptions to their concrete applications. The case studies complement the literature review and enrich the lessons learned and findings to advance the diversity of methodologies and approaches in this field.

The first case study from Kenya illustrates a top-down approach for EWS, in which communities were consulted to inform the design of EWS. It is based on research that is part of the United Nations Environment Programme (UNEP)'s work in a Climate Change Early Warning Project (CLIM-WARN), aimed at informing the design of a participatory, multihazard EWS in Kenya. Researchers from UNEP conducted household surveys and focus group discussions at different sites (three peri-urban villages in Nairobi; one urban and two rural villages in Kisumu, on the northeast shore of Lake Victoria; and rural villages in Kwale County, south of Mombasa, and Turkana County, west of Lake Turkana) to provide detailed information on the state of vulnerability, access to communication devices, and response among users to early warnings, to understand how to improve the delivery of climate information.

The second case study from Hawai'i is representative of a "hybrid" approach, where local knowledge and expertise for identifying environmental indicators and warnings are coupled with government warning systems technology in the Hawai'ian Islands. A community vulnerability assessment of coastal communities on the northern shores of the islands of Kaua'i and O'ahu provided a mixed qualitative and quantitative critique of EWS in place in these communities, and the gaps identified in the risk communication process were addressed by promoting involvement of local communities in risk alert dissemination.

The third case study from Sri Lanka is the closest to a CCEWS. Researchers at the University of Colombo analyzed a community-based landslide EWS in the town of Rattota area in Matale District, central Sri Lanka, and people's participation as part of the project titled "Living in Risks." Sample household surveys and in-depth interviews were conducted among the people who lived in flood- and landslide-prone areas. The results helped understand existing community-based EWS at local level and the different challenges faced.

2.5 Scope and Limits

The scope of this article is limited by the depth of the case studies presented, and the choice of the authors to reflect on the design of EWS through investigating pathways to involving local communities. Several aspects related to community participation and EWS effectiveness are not included. The study does not analyze the role of governance systems, which influence community participation and effectiveness of EWS. We also acknowledge that people's priorities and livelihood conditions may affect their participation and appropriation of EWS, and that ensuring the participation of a community as a whole in EWS is difficult. Different groups within a society may also be differently involved in the participation process, and thus benefit unequally from it (Mansuri and Rao 2013). These issues were not investigated because the case studies used in the research did not provide enough information to conduct an in-depth assessment of the political and socioeconomic factors contributing to people's participation in EWS.

The limitations related to the choice of the three case studies are due to the fact that the cases were conducted by different researchers leading unrelated studies. Their depth and contribution to this study are not consistent. To limit inconsistencies between the three cases, data from each case were treated according to this study's aim. This made it possible to produce results that are consistent and valuable to advance the science and practice on participatory EWS, when coupled with the literature review. We found that the three case studies are representative of various degrees of involvement of local communities in EWS, from top-down to more participatory processes. This is useful and informs our research and reflections.

3 Results

This section presents the results of each case study regarding the conception and implementation of EWS. For each case, we underline the major natural hazards affecting the country or region, look at the approach adopted to set up EWS with a specific focus on community involvement, and identify the challenges and successes encountered. This information will be useful to compare each case study in the next section in order to draw conclusions about engaging with communities for an improved early warning process.

3.1 Case Study 1: The Need for Community-Tailored Early Warning Systems in Kenya

A country assessment of climate hazards led by the Kenyan Disaster Risk Reduction Initiative Activities (DARA 2012) shows high vulnerability to drought and moderate vulnerability to floods in Kenya. The frequency of these hazards and the level of damage caused are predicted to increase with climate change. Hazard risks do not only depend on the hazard type but also on the location of the affected communities, which influences their exposure to risks, access to information, and capability to respond. Droughts affect approximately 70 % of Kenya's land area and are most severe in the eastern, northeastern, and coastal provinces. Floods have been widespread in western and coastal provinces of the country, especially during rainy seasons (Senaratna et al. 2014). While several EWS already exist in Kenya, they are not coordinated and often assume a top-down approach. Different institutions are responsible for warning of different hazards (Senaratna et al. 2014) and communication gaps exist, indicating a need for greater community involvement.

Surveys conducted by UNEP researchers among rural and urban communities in Nairobi, Kisumu, Kwale, and Turkana in 2014 revealed that different communities have different livelihood profiles and the resulting different needs will influence the design of EWS. One important finding from the survey was that sources of income vary greatly between regions: while urban communities have diverse income sources, ranging from retail businesses (for example, shops and supermarkets) to the transport sector (for example, taxi driving or motorcycle taxis called *Bodabodas*), agriculture is the dominant sector in rural areas where most households depend on farming and/or pastoralism for their livelihood. This can affect the level of resilience to natural hazards as households with only one form of income—pastoralism—may have limited options for alternative livelihood sources during droughts. This reflects a critical need for EWS for these vulnerable communities.

The level of education and access to communication devices also varies from location to location, and directly affects response capability to natural hazards. Nairobi has the highest level of formal education among the selected sites. In remote and marginalized areas, such as Turkana County, a quarter of the population does not have any formal education, and none of the respondents in the sampled villages had attained a university education. Access to information and technology is relatively good in Nairobi where a large part of the population receives information through diverse channels, including mobile phones, computers, radios, and TV, while in rural locations like Turkana, Kisumu, and Kwale only a fraction of the population uses radios and mobile phones. These findings indicate that the type of EWS must be suited to the target community, including their specific needs in terms of use of communication devices for warning issuance and capacity to understand risks and interpret them.

Overall, the study indicates that livelihood surveys are critical tools to identify community needs and help design appropriate EWS. While exploring pathways to involve local communities in the design of EWS, the case study essentially highlights that some communities are likely to be more resilient to hazards than others due to a higher level of socioeconomic development, livelihood diversification, access to technology and information, or a higher level of education. Regions with lower education levels and limited access to information through TV, radio, or text messaging will likely require the involvement of traditional institutions, such as chiefs, as critical vehicles for warning delivery. Urban areas such as Nairobi may use mobile phones as an effective way to deliver warnings and spread information. The study demonstrates that EWS need to be flexible in design to accommodate these local differences but still ensure standard information delivery. Providing warning services of similar standard, but tailored to each community's need, poses a governance challenge with potentially large financial costs.

3.2 Case Study 2: Coupled Early Warning Systems in Hawai'i

Rural coastal communities in the Pacific, including those in the Hawai'ian islands, are at extreme risk to impacts from acute hazards such as tsunami and flash flooding, and chronic hazards such as drought and coastal erosion. Vulnerability is exacerbated by extreme isolation and a high dependency on imported energy and food (HSCD 2010). Current limitations of risk reduction and hazard mitigation measures include a poor understanding of risks related to natural hazards coupled with inadequate policy and planning integration of risk reduction strategies across sectors, particularly at the community level (HSCD 2010). This necessitates the codevelopment of local risk reduction strategies, including the implementation of EWS that build on and integrate local and traditional knowledge, strategies, and networks with official government early warning mechanisms, appropriate for the spectrum of hazards these communities are prone to.

A community-based participatory research and planning project was launched across the North Shore communities of the islands of Kaua'i and O'ahu (Henly-Shepard 2013a, b). The project developed and supported local disaster resilience committees representing residents, businesses, governmental, and nongovernmental stakeholders. The project was implemented by Disaster Resilience L.L.C. and focused on participatory disaster resilience research and planning, integrating local hazard mitigation, risk reduction, and climate change adaptation (Henly-Shepard et al. 2014, 2015). A community vulnerability assessment was first conducted and provided a qualitative critique of current EWS in place in communities, including: (1) state governmental tsunami evacuation warning sirens; (2) multigovernmental agency, multihazard warnings by email, text messaging, radio, and television; and (3) verbal informing through social networks. Results from the assessment were used to address failures of existing communication media and resulted in expedited trouble-shooting (for example, fixing broken sirens and improving online warning platforms).

More importantly, results from the assessment indicated that verbal informing as a notification mechanism is still highly relevant and critical in rural communities, particularly for warning and evacuating persons with limited access to communication devices, reduced ability to vacate exposed areas on their own (for example, elderly), or those who did not hear the governmental warnings. However, the social networks needed for this have been degraded due to a loss in local residency (for example, new residents have settled down while local residents are moving away, in search for job opportunities) and the reduction in community ties (Henly-Shepard 2013a; Henly-Shepard et al. 2014). In an attempt to improve warning communication and counter the erosion of traditional knowledge and networks, the project contributed to the creation of committee-run social media sites to share traditional knowledge of risk and risk management, disseminate disaster information, and provide grassroots early warning mechanisms. To foster long-term disaster risk reduction, traditional knowledge and experience in EWS was coupled with technology: the disaster resilience planning project included the use of participatory mapping utilizing Geographic Information Systems, to offer spatial representations of changing trends in ecological factors, habitat, land use and land cover, among other aspects, and to facilitate map-making to inform adaptation planning and risk reduction measures (Henly-Shepard 2013a). Additional tools include the National Oceanic and Atmospheric Administration (NOAA) sea level rise viewer, to illustrate how particular areas will be affected by sea level rise scenarios, stimulating discussion of potential impacts among the vulnerable communities and prioritizing risk reduction strategies, policies, and projects.

Overall, the study demonstrated the benefits of combining science and technology with local expertise. Surveys indicated that long-term residents and a few remaining indigenous people possess and practice the traditional and local knowledge of how to reduce risk, mitigate hazard impacts, and adapt practices and livelihoods to climatic shifts or other changes. Local strategies include stocked food, water supplies, and emergency rations, social support, family garden, and access to safe space for evacuation (Henly-Shepard et al. 2014). However, loss of local residents has not only eroded social network connectivity but also led to a loss of this local knowledge. In response, the disaster resilience planning project has worked to invite knowledgeable *kupuna* (elders) to share this knowledge with the committee and the community at large. In support of this coupled technological-traditional knowledge approach and to identify threats quickly and promote long-term risk reduction, the disaster resilience committees are utilizing the findings to promote: (1) the protection of critical habitats and ecosystem services; (2) the diversification of livelihoods and livelihood opportunities; and (3) improved disaster risk reduction through training, resource access, and the regeneration of social networks.

3.3 Case Study 3: Community-Based Early Warning Systems in Sri Lanka

One-third of the Sri Lankan population is engaged in climate sensitive livelihoods, including agriculture (rice, tea, rubber, and coconut cultivation) and fisheries (Jayatilake 2008), and 25 % live in coastal areas. Coastal communities, both rural and urban, are at risk of sea level rise, increasing temperatures, storms, and other hazards, such as saltwater intrusion (Jayatilake 2008). In addition, 30 % of Sri Lanka's land area is prone to landslides, especially the following 10 districts: Badulla, Nuwara Eliya, Kegalle, Ratnapura, Kandy, Matale, Kaluthara, Mathara, Galle, and Hambantota (Bandara 2005). Sri Lanka, as a developing island nation, is vulnerable to climate change and the main sectors under threat include water (quantity and quality); agriculture (raised temperatures and unpredictable monsoon rains); health; and geographic locations such as the coastal belt.

Over a million Sri Lankan people, mainly in rural areas, are beyond the reach of communication infrastructure or lack the basic information on local hazards and the resources to prepare themselves for disasters (UNDP 2009). In 2009, as a pilot project to reduce landslide risks, a number of community-based early warning systems were introduced in selected landslide-prone areas in the Matale district. Communities were involved in risk education programs and were trained on evacuation paths, engaged in evacuation drills in an emergency situation, and were also involved in the risk detection process. Fiberglass rain gauges were introduced in the communities as an EWS (Wijesinghe 2014). Designated community observers were educated on how to measure the portable plastic rain gauges that were marked by different colors: green for water height between 75 and 100 mm; yellow for water height between 100 and 150 mm; and red for water height of 150 mm or above. The red zone indicates that it is time for communities to evacuate for safety.

The community observers were responsible for the daily monitoring of the rain gauges and verbally informing the surrounding households on the gauge status to ensure clear and consistent communication to all residents at risk. Between October and November 2010, 121 families used this method to evacuate to safer places during landslides. The method was also tested in other districts.

Involving the communities in such EWS proved critical, especially for those located in at-risk areas and refusing permanent relocation. A survey with households in the Punchi Rattota area, conducted in 2010, indicated that despite warnings to vacate the place where they lived in view of the high landslide risks, the community refused to move away because they were living on their ancestral land. As an alternative, a rain gauge monitoring system managed by the community was introduced to provide warnings and facilitate temporary evacuation in case of landslide risks. The system requires strong involvement and participation of the community. However, in-depth interviews with community leaders who were actively engaged in this risk monitoring system revealed that, while continuous active community involvement for a longer period of time in community-based EWS is essential to protect communities from landslides, this involvement is difficult to ensure. In the pilot areas, well-off community leaders who were actively involved in the EWS progressively moved out to more secure locations. Finding new community leaders to replace them and manage the local EWS was a difficult task. At the same time, the movement of key leaders to less vulnerable areas indicates that knowledge transfer for risk reduction did work.

Overall, the project demonstrates the importance of community-based early warning systems in countries like Sri Lanka, highly exposed to natural hazards, where many live in remote rural areas beyond the reach of communication on hazard and early warnings. It also highlights the need to engage with community members to implement such systems and allow quick dissemination of risk warnings in remote areas. The project finally highlights the benefits of risk education to raise awareness and preparedness; interviews with household heads in the study area indicated an increased understanding of landslides and tsunami risks as well as of available options when receiving the evacuation call from the media or by any other formal or informal method.

4 Discussion

In this section we compare results from the three case studies in order to understand the degree of community involvement in each case, and the related challenges or successes regarding the implementation and effectiveness of the EWS. Based on this information, we then reflect on the limits of EWS and discuss opportunities for more inclusive design of EWS, defining them not as risk detection and warning tools but as societal processes.

4.1 Evidence from the Case Studies

Evidence from the case studies highlights that different communities have different needs, based on their location, access to risk information, use of communication devices, or level of response capability. While similar in demonstrating a need for community-tailored EWS, each case also offers a different insight on how local communities can be engaged or involved in EWS from a more top-down approach (Kenya) to a more participatory one (Sri Lanka). Key results from each case are summarized in Table 1.

The case studies illustrate how communities can be involved in different links of the EWS. The Kenyan case reflects the most top-down approach as communities were only approached through surveys that aimed to inform the design of EWS. The outcomes indicate that EWS cannot be implemented uniformly across communities but must be tailored to the particular needs of each group. Tailored EWS are critical to ensure that existing inequalities among vulnerable groups are not emphasized, but the process can be expensive. Ensuring warning services of similar standards across diverse communities through a centralized EWS is costly, whereas localized EWS, driven by the beneficiary community, can facilitate the delivery of services tailored to each community's needs and could reduce implementation costs.

The Hawai'i case study also highlighted a necessity for tailored use of communication networks, especially focusing on the vulnerable groups with limited access to communication technologies. Again, this demonstrates that EWS cannot be applied uniformly in a society given different levels of capacity and access to critical resources. The case also demonstrated that while keeping alive traditional knowledge of risk management and social networks is challenging, it is critical to ensure that the most vulnerable groups are not left behind when a risk is detected. Using existing networks for alert issuance and risk management is an important pathway to directly involving communities in their EWS.

The relevance of traditional knowledge and communication systems was especially underlined in the Sri Lankan case study where an EWS was set up for a population with limited access to communication networks. In this context, social networks, and traditional institutions and systems (for example, the role chiefs play) were critical in informing vulnerable groups about the risks related to natural hazards. Because of the remote location of some communities, it was also critical that the risk monitoring and detection processes remain in the hands of local actors. Community members were trained to become key leaders to operate their own EWS. However, the experience highlighted the difficulty to ensure long-term community involvement in EWS, especially in the context of increased migrations and urbanization.

Although some case studies are very close to a CCEWS (for example, in Sri Lanka), all were initiated by an agent external to the beneficiary community (that is, a government or an international agency) whereas participatory approaches highlight the need to have a process that is initiated and owned by the beneficiaries. Perhaps a way to overcome the challenges illustrated in the three case studies, including the cost issue (for example, in Kenya),

Table 1 Challenges and successes in involving local communities in Early Warning Systems (EWS) in Kenya, Hawai'i, and Sri Lanka

Country variables	Kenya	Hawa'i	Sri Lanka
Hazards	Multihazards	Coastal storms, hurricanes, tsunamis, floods	Tsunamis and landslides
EWS link	Dissemination of information and response capability	Dissemination of information, risk education, and warning issuance	Risk detection, monitoring, warning issuance, and risk education
Community involvement	Survey to identify capability needs and access to information	Grassroots participatory research and planning process	In charge of monitoring precipitation gauges and issuing risk warnings
Success	Attempt to design a prototype EWS that is tailored to meet the needs of all users	Regenerated community networking and grassroots mobilization to support knowledge transfer for improved local DRR and integrated EWS	Successful evacuation in landslide-prone areas during the length of the project
Challenges	Providing warning services of similar standard but tailored to each community's needs	Erosion of traditional EWS knowledge and long-term disaster risk reduction	Maintaining long-term community involvement especially after the project's life

the erosion of traditional risk management knowledge (for example, in Hawai'i), or the difficulty to ensure long-term community engagement in the EWS (for example, in Sri Lanka), is through the design of EWS that are truly initiated and run by the beneficiaries.

4.2 Reflections on Early Warning Systems

Each case study is an illustration of how communities can be involved in EWS, and what the values and challenges are. The challenges raised call for a broader reflection around the design, implementation, and management of EWS. The design (top-down or community-centric) of EWS may be influenced by the type of hazard targeted. Large-scale, creeping environmental problems of a long-term and cumulative variety (Glantz 1994) such as droughts are more suitable for centralized systems whereas localized events like flash floods can be managed at the local level. Some hazards also require an enhanced level of technology to make early warnings accurate (for example, detection of cyclones) and this will affect the design and the degree of community involvement in EWS. Yet, community still plays a great part in the communication and preparedness planning phases. Hall (2007) highlighted that EWS are an extension of existing risk management practices, often embedded in indigenous knowledge. Maguire and Hagan (2007) and Kelman and Glantz (2014) indicated that communities already possess resilient properties to face risks that can be enhanced through information access, training, and education. The Sri Lankan and Hawai'ian cases emphasize the role of local knowledge and social networks in risk detection and warning issuance, as well as how communication and preparedness planning can benefit from involving the local communities.

If the literature and the cases suggest that participation of local communities in EWS is critical, the scope of community involvement as well as the pathways to foster such involvement appear to vary, from community consultation in Kenya to a stronger engagement in hazard detection and warning issuance in Sri Lanka. These views, even the most participatory one, reflect a traditional conception of EWS. Beyond enhancing community participation in each of the links of EWS, Kelman and Glantz (2014) argue, as a further step, that EWS should be conceived as part of the local societal process. The system should be embedded within a community rather than conceived as a technological tool that detects risks and issues warnings. This conception of EWS is broader and more flexible than the traditional E-2-E linear approach. The Hawai'ian and Sri Lankan case studies illustrate steps towards embedding EWS in societal processes because risk detection and dissemination are based on existing institutions and knowledge (which contributes to valuing and empowering the beneficiaries), and rely on existing social networks and communication channels (which improves risk warning issuance). It also appears that community involvement is a way to emphasize the "communication" link of EWS, shifting from the "last mile approach" that assumes EWS knowledge is external to local communities, to the "first mile approach" that places people at the center of the EWS process where they can assist in providing information for early warning actions (Kelman and Glantz 2014).

If EWS are conceived as societal processes, then education becomes a critical component. Kelman and Glantz (2014) highlight that education can be a vehicle for the transmission of traditional knowledge through programs and reinforce coupled science-local knowledge based

EWS. By preserving and sharing local knowledge, education can also ensure those carrying this knowledge feel valued in the early warning process, which could in turn foster long-term community engagement. By raising awareness, informing on potential indicators to detect a risk and underlying existing options to mitigate risks, education can improve response capability and resilience to natural hazards. Scientists and practitioners could also learn from local knowledge, experience, and histories of emergency management, maintained and shared through education programs. Acknowledging the value of local knowledge is a step towards building respectful relationships between practitioners and communities, and facilitates the coupling of local EWS with expert knowledge on risk detection and monitoring.

5 Conclusion

Early warning systems for natural hazards are a vital infrastructure for society. If well conceived, they can contribute to building resilience among vulnerable groups. More specifically, community-centric EWS can contribute to empowering communities to make decisions to ensure their safety and protection in the context of a changing climate. A truly participatory approach requires practitioners to step away from the traditional E-2-E view of EWS and adopt a perspective where EWS is a process rooted within a community.

Participatory EWS should not be built on the rejection of modern science and technology. Rather, coupling knowledge systems—traditional and science-based—can contribute to improving risk detection and monitoring as seen in the Hawai'ian case study. Similarly, communication and warning issuance can use modern channels. Social media and community disaster mapping have been used in postdisaster response and may have a role to play in CCEWS. In areas of the world where there is a surge in mobile phone growth and open source data collection, like in Kenya, communities can be involved in monitoring prior to warning dissemination.

Ultimately, the only way for a system to respond to a community's specificities and be sustained over time is if the need for one is expressed by the community and is prioritized among other needs. Practitioners and scientists are encouraged to step away from the current view of EWS as expert-driven linear tools based on scientific expertise, and provide the necessary support to the initiative that is proposed, supported, and controlled by those on the front line when hazards occur.

Acknowledgments This work was initiated during the "Resilience Academy," which took place in Dhaka, Bangladesh, in September 2013. The Academy is an initiative of the Munich Re Foundation, the United Nations University Institute for Environment and Human Security (UNU-EHS), and the International Centre for Climate Change and Development (ICCCAD). The authors, Fellows of the Resilience Academy, wish to thank the organizers of the Resilience Academy for making this study possible, as well as all the participants in the surveys that took place in the case study countries.

References

Archer, E.R.M. 2003. Identifying underserved end-user groups in the provision of climate information. *Bulletin of the American Meteorological Society* 11(84): 1525–1532.

Bailey, R. 2013. *Managing famine risk: Linking early warning to early action*. London: Chatham House Report.

Bandara, R.M.S. 2005. Landslides in Sri Lanka. *Vidurava* 22(2): 9–13.

Basher, R. 2006. Global early warning systems for natural hazards: Systematic and people-centered. *Philosophical Transactions of the Royal Society* 364(1845): 2167–2182.

Baudoin, M.-A., A. Cuni-Sanchez, and B. Fandohan. 2014. Small scale farmers' vulnerability to climatic changes in southern Benin: The importance of farmers' perceptions of existing institutions. *Mitigation and Adaptation Strategies for Global Change* 19(8): 1195–1207.

Baudoin, M.-A., and T. Wolde-Georgis. 2015. Disaster risk reduction in the Greater Horn of Africa. *International Journal of Disaster Risk Science* 6(1): 49–61.

Blaikie, P., T. Cannon, I. Davis, and B. Wisner. 1994. *At risk: Natural hazards, people's vulnerability and disasters*. London: Routledge.

Carr, E.R. 2014. From description to explanation: Using the livelihoods as intimate government (LIG) approach. *Applied Geography* 52: 110–122.

Carr, E.R., and K.N. Owusu-Daaku. 2016. The shifting epistemologies of vulnerability in climate services for development: The case of Mali's agrometeorological advisory programme. *Area* 48(1): 7–17.

Chambers, R. 2008. *Revolutions in development inquiry*. London: Earthscan.

Clark, H. 2012. Building resilience: The importance of prioritizing disaster risk reduction. UN Hopkins lecture. Canterbury, New Zealand: University of Canterbury.

DARA. 2012. *Climate vulnerability monitor 2nd edition: A guide to the cold calculus of a hot planet*. http://daraint.org/climate-vulnerability-monitor/climate-vulnerabilitymonitor-2012/country-profile/?ountry=Kenya. Accessed 16 Nov 2015.

Gaillard, J.C. 2010. Vulnerability, capacity and resilience: Perspectives for climate and development policy. *Journal of International Development* 22(2): 218–232.

Glantz, M.H. 1994. Creeping environmental phenomena: Are societies equipped to deal with them? *Workshop on creeping environmental phenomena and societal responses to them*, 7–9

February 1994, National Center for Atmospheric Research, Boulder, Colorado, USA.

Glantz, M.H. 2009. *Heads up! Early warning systems for climate-, water- and weather-related hazards*. Tokyo: United Nations University Press.

Glantz, M.H., and M.-A. Baudoin. 2014. *Working with a changing climate, not against it—Hydro-meteorological disaster risk reduction: A survey of lessons learned for resilient adaptation to a changing climate*. Boulder: Consortium for Capacity Building.

Guha-Sapir, D., P. Hoyois, and R. Below. 2014. *Annual disaster statistical review 2013: The numbers and trends*. Brussels: Centre for Research on the Epidemiology of Disasters. http://www.cred.be/sites/default/files/ADSR_2013.pdf. Accessed 11 Jan 2016.

Hall, P. 2007. Early warning systems: Reframing the discussion. *Australian Journal of Emergency Management* 22(2): 1324–1540.

Hellmuth, M.E., A. Moorhead, M.C. Thompson, and J. Williams (eds.). 2007. *Climate risk management in Africa: Learning from practice*. New York: International Research Institute for Climate and Society, Columbia University.

Henly-Shepard, S. 2013a. *Hanalei to Ha'ena community disaster resilience plan*. Prepared by Disaster Resilience L.L.C. and the Hanalei Watershed Hui. Prepared for the Hanalei to Ha'ena Community Disaster Resilience Committee, Honolulu, Hawai'i.

Henly-Shepard, S. 2013b. *North Shore O'ahu community disaster resilience plan*. Prepared by Disaster Resilience L.L.C. and the North Shore Disaster Preparedness Steering Committee. Prepared for the North Shore Disaster Preparedness Steering Committee, Honolulu, Hawai'i.

Henly-Shepard, S., C. Anderson, K. Burnett, L.J. Cox, J.N. Kittinger, and M. Ka'aumoana. 2014. Quantifying household social resilience: A place-based approach in a rapidly transforming community. *Natural Hazards* 75(1): 343–363.

Henly-Shepard, S., S.A. Gray, and L.J. Cox. 2015. The use of participatory modeling to promote social learning and facilitate community disaster planning. *Environmental Science & Policy* 45: 109–122.

Hickey, S., and G. Mohan. 2004. Toward participation as transformation: Critical themes and challenges. In *Participation—From tyranny to transformation?* ed. S. Hickey, and G. Mohan, 3–24. London: Zed Books.

Holloway, A., and R. Roomaney. 2008. *Weathering the storm: Participatory risk assessment for international settlements*. Cape Town, South Africa: Disaster Mitigation for Sustainable Livelihoods Programme, University of Cape Town.

HSCD (Hawai'i State Civil Defense). 2010. *State of Hawai'i multi hazard mitigation plan, 2010 update. Hawai'i State Civil Defense*. http://www.scd.hawaii.gov/documents/HawaiiMultiHazardMitigationPlan2010PUBLIC.pdf. Accessed Mar 2015.

IFRC (International Federation of Red Cross and Red Crescent Societies). 2012. *Community early warning systems: Guiding principles*. Geneva: IFRC.

IPCC (Intergovernmental Panel on Climate Change). 2012. *Special report on managing the risks of extreme events and disasters to advance climate change adaptation*. Cambridge: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2013. *Climate change 2007: The IPCC fourth assessment report*. Cambridge: Cambridge University Press.

Jayatilake, A. 2008. Climate change due to global warming: A global challenge in Sri Lanka perspective. *Economic Review* 34: 9–14.

Kelman, I., and M.H. Glantz. 2014. Early warning systems defined. In *Reducing disaster: Early warning systems for climate change*, ed. A. Singh, and Z. Zommers, 89–108. London: Springer.

Lallau, B. 2008. African farmers between vulnerability and resilience. For the capabilities approach to risk management (*Les agriculteurs africains entre vulnérabilité et résilience. Pour une approche par les capabilités de la gestion des risques*). *Revue Française de socio-économie* 1: 177–198 (in French).

Leary, N., C. Conde, J. Kulkarni, A. Nyong, and J. Pulhin. 2008. *Climate change and vulnerability*. London: Earthscan.

Maguire, B., and P. Hagan. 2007. Disasters and communities: Understanding social resilience. *Australian Journal of Emergency Management* 22(2): 16–20.

Mansuri, G., and V. Rao. 2013. *Localizing development: Does participation work?* Washington, DC: World Bank.

Maskrey, A. (ed.). 1997. *Report on national and local capabilities for early warning*. Geneva: International Decade for Natural Disaster Reduction Early Warning Programme.

Mercer, J., I. Kelman, L. Taranis, and S. Suchet-Pearson. 2009. Framework for integrating indigenous and scientific knowledge for disaster risk reduction. *Disasters* 34(1): 214–239.

Nicholson, S.E. 2014. A detailed look at the recent drought situation in the Greater Horn of Africa. *Journal of Arid Environments* 103: 1–79.

Roncoli, C., C. Jost, P. Kirshen, M. Sanon, K.T. Ingram, M. Woodin, L. Somé, F. Ouattara, et al. 2008. From accessing to assessing forecasts: An end-to-end study of participatory climate forecast dissemination in Burkina Faso (West Africa). *Climatic Change* 92(3–4): 433–460.

Senaratna, N., M.-A. Baudoin, A. Oluoko-Odingo, D.W. Wepukhulu, and A.S. Mwadali. 2014. Natural hazards and climate change in Kenya: Minimizing the impacts on vulnerable communities through early warning systems. In *Reducing disaster: Early warning systems for climate change*, ed. A. Singh, and Z. Zommers, 355–375. London: Springer.

Shah, P., C.I. Speranza, R. Opiyo, and J. Ngaina. 2012. *Options for improving the communication of seasonal rainfall forecasts to smallholder farmers: The case of Kenya*. Bonn: German Development Institute/Deutsches Institut für Entwicklungspolitik (DIE).

Sorensen, J. 2000. Hazard warning systems: Review of 20 years of progress. *Natural Hazards Review* 2(1): 119–125.

Tozier de la Poterie, A., and M.-A. Baudoin. 2015. From Yokohama to Sendai: Approaches to participation in international disaster risk reduction frameworks. *International Journal of Disaster Risk Science* 6(2): 128–139.

Udu-gama, N. 2009. Mobile cell broadcasting for commercial use and public warning in the Maldives. Sri Lanka: LIRNEasia. http://preparecenter.org/sites/default/files/11235_cbmaldivesfinal20090411.pdf. Accessed 21 Apr 2016.

UN (United Nations). 1994. Yokohama strategy and plan of action for a safer world: Guidelines for natural disaster prevention, preparedness and mitigation. http://www.unisdr.org/files/8241_doc6841contenido1.pdf. Accessed 19 Apr 2016.

UNDP (United Nations Development Programme). 2009. *Institutional and legislative systems for early warning and disaster risk reduction*: *Sri Lanka*. Bangkok: United National Development Programme Regional Centre.

UNECA (United Nations Economic Commission for Africa). 2011. *Vulnerability and climate change hotspots in Africa—Mapping based on existing knowledge*. Working paper 2. Addis Ababa: African Climate Policy Centre (ACPC).

UNISDR (United Nations International Strategy for Disaster Reduction). 2009. *Terminology on disaster risk reduction*. Geneva: UNISDR.

UNISDR (United Nations International Strategy for Disaster Reduction). 2015. *Sendai framework for disaster risk reduction 2015–2030*. http://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf. Accessed 19 Apr 2016.

Villagran de Leon, J.C., J. Bogardi, S. Dannenmann, and R. Basher. 2007. Early warning systems in the context of disaster risk management. *Agriculture and Rural Development* 1: 43–45.

Wijesinghe, M. 2014. Community based early warning systems for landslides: Case of four Grama Niladari divisions in Matale District. Dissertation, Faculty of Graduate Studies, University of Colombo, Colombo, Sri Lanka.

World Bank. 2012. Disaster risk financing and insurance in sub-Saharan Africa: Review and options for consideration. http://www.preventionweb.net/go/31323. Accessed 23 Feb 2016.

World Bank. 2013. Turn down the heat: Climate extremes, regional impacts and the case for resilience. A report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics. Washington, DC: World Bank.

Zommers, Z. 2014. "Follow the spiders" ecosystems as early warnings. In *Reducing disaster: Early warning systems for climate change*, ed. A. Singh, and Z. Zommers, 339–353. London: Springer.