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Early warning systems and livelihood resilience: Exploring opportunities for community participation

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Abstract

Climate and natural hazards are increasing in intensity, frequency and complexity. Their related impacts have powerful implications for humanity, particularly communities with deep reliance upon natural resources. The development of effective Early Warning Systems could contribute to foster livelihood resilience by improving coping mechanisms and even enhancing adaptive capacity. However, current shortcomings in early warning systems' conception and applications undermine risk reduction at the grassroots level, which contribute to loss of lives and shocks to livelihoods. This paper provides multiple case studies illustrating best practices and challenges of participatory early warning systems, implemented at various scales in at-risk communities. Results indicate a need to significantly improve the way early warning systems are designed and applied. The paper suggests an integrated cross-scale approach that ensures the involvement of at-risk population from the risk detection to emergency management processes. Yet, such a participatory approach also raises multiple challenges, opening pathways for future research.

Keywords: early warning; community; resilience.

A. Introduction

Our climate is changing; observed impacts include increased temperature, changes in rainfall patterns and seasonality, as well as modification in intensity, frequency and location of natural hazards (Basher, 2006; IPCC, 2007). Stronger hydro-meteorological events observed over the last decades suggest increased human, socio-economic and environmental damages or losses for the next decades (Basher, 2006).

A high degree of vulnerability to natural and climate hazards is often pointed out in developing countries, especially amongst the poorest households and those located in remote areas (Basher, 2006). Yet, developed regions are also at risk, specifically areas exposed to hazards including coastal zones and small islands (e.g. Hawaii) (IPCC, 2007). Societies reliant upon natural resources for their livelihood, e.g. farmer communities in the Sahel, are also more affected by disruptive shifts in ecological dynamics and climate patterns. Drought or changes in rainfall seasonality strongly impact capacities to sustain life, affecting livelihood conditions (Hellmuth et al., 2007).

Communication through early warning systems provides opportunity to reduce disaster risk by enhancing preparedness; thus, it contributes to strengthen livelihood resilience at the local level (Glantz and Baudoin, 2014; Hall, 2007). There is already a rich body of literature on early warning systems - especially since the International Decade for Natural Disaster Reduction (IDNDR) (Hall, 2007). However, Archer (2003) and Glantz and Baudoin (2014), note that communication gaps and limited access to relevant climate and weather information among vulnerable groups are important features limiting coping and response capacities in societies at risk. Such communication gaps are yet to be addressed as they remain less studied in the literature assessing local vulnerability stressors: these research often focus on economic, institutional and socio-cultural drivers for vulnerability (Leary et al., 2008; O'Brien et al., 2010).

Similarly, the concept of 'resilience', also at the core of this paper, has been defined both in academia and practice, often referring to the ability of a system to absorb shocks, to anticipate and avoid harm, and to reconfigure, 'bounce back' or respond positively after a disturbance (Alexander, 2013; Folke et al., 2010; Gaillard, 2010; Gubbels, 2012). Many government and non-governmental organizations are now seeking to strengthen the resilience of society to natural and man-made disasters (Maguire and Hagan, 2007). In the field of development aid and the context of climate change, practitioners and aid agencies also emphasize the need to build resilience among communities in order to strengthen their capacities to face increased climate risks (Bailey, 2013; USAID, 2012; UNISDR, 2013).

This paper focuses on the links between early warning systems and livelihood resilience. It especially discusses the conception and application of early warning systems, with the goal to partially fill in the research gap on communication weaknesses, a limit that contribute to increase local vulnerability to natural and climate hazards. As Mercer et al. (2009) suggest a participatory approach in the field of disaster risk reduction; we explore opportunities and challenges to reduce the impacts of disasters and to strengthen livelihood resilience in the context of a changing climate, using participatory early warning systems. The proposed model is a cross-scale approach for

integration and communication among scientists and communities at risk, an approach which would not only favour ownership of the early warning systems by at risk community, but also foster sustained local participation and long-term support to such systems. As a result, livelihood resilience may be enhanced. To achieve cross-scale integration among scientists and communities and to support long-term involvement, we argue that the application of early warning systems must be reconsidered: we suggest an approach that is less science-driven in favour of placing vulnerable communities at the core of early warning systems.

This paper begins by providing general information about early warning systems and discussing the potential of these systems to enhance livelihood resilience. The second section of the paper highlights some case studies, as concrete examples of community based early warning systems in Kenya, Hawai'i and Sri Lanka, to underline some of the successes and challenges in the conceptualization and operationalization of community-based early warning systems. The main challenges relate to communication gaps, questions on how to integrate indigenous risk knowledge with scientific perspectives, and the difficulty of sustaining community engagement in the process. Finally, the conclusions and way forward section identifies gaps and opportunities to improve risk communication within early warning systems.

We find that there is a critical need to place at risk communities at the core of the early warning process, from hazard detection to emergency management. Moreover, early warning systems must be tailored to a community's needs. To realize this, we propose to explicitly integrate feedbacks from the local communities that regularly face disasters' risks in the design and implementation of early warning systems. This feedback loop, implied in existing design for early warning systems, is actually not explicitly applied. In other words, most systems tend to be science and expert driven, thus, they are somehow disconnected from local realities and needs in terms of early warning and risk preparedness. Developing partnerships among scientists and vulnerable communities would provide opportunities for sustained local participation in early warning systems. In short, there is a critical need to rethink the way early warning systems are formed and applied, with a detachment from the science-driven nature to the benefit of real integration of the community at risk.

B. Early Warning Systems and livelihood resilience

1. Disasters

The United Nations Office for Disaster Risk Reduction (UNISDR, 2009), defines disasters as: "A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources". Disasters are a result of intense or disruptive events, combined with society's vulnerability to hazards and its level of capacities to cope with, or respond to the hazard (Blaikie, 1994). In addition to seriously disrupting livelihoods and economic activities, disasters are significant burdens and may hinder progress in developing countries. Over the last decade, the world has witnessed a high number of natural and climate related hazards which caused the death of millions and significant economic and material losses globally (Basher, 2006).

2. What are Early Warning Systems and how do they work?

Early warning systems are defined as: "A set of capacities needed to generate and disseminate timely and meaningful warning information; to enable individuals, communities and organizations threatened by hazards to prepare and to act appropriately the possibility of harm or loss" (UNISDR, 2009). They have been developed for a wide variety of risks, however, this paper focuses on early warning systems for climate related hazards, such as storms, floods, droughts, landslides, and tsunamis.

Early warning systems are commonly viewed as a linear chain from the risk diagnosis by meteorologists, geologists and other specialists to the dissemination of alerts to high risk groups, this is often referred to as the "End-to-End" (or E2E) model (Basher, 2006; UNISDR, 2009). This chain generally includes four main components: (1) risk knowledge; (2) risk monitoring and warning services; (3) risk dissemination and communication; and (4) response capability. Those establishing early warning systems often focus on modelling geophysical processes to monitor risks and less consideration is given to vulnerability and the response processes (Basher, 2006). In practice, systems are usually monitored and controlled by regional or national meteorological services with limited interaction and involvement of the local communities at risk (Glantz and Baudoin, 2014). In other words, the E2E chain for early warning systems strongly focuses on technological issues and monitoring functions, rather than on capability and capacity building within communities.

The science behind early warning systems is not perfect, for instance, tsunami early warning systems are based on the precursor of seismic observations in the ocean, which do not always result in a tsunami. Our current knowledge of oceanic responses to such shocks is not yet accurate and this can sometimes result in the dissemination of false alerts. Though accurate risk diagnoses are an important basis to formulate and disseminate relevant warnings, they are not the most important part of an early warning system. No matter how specific the science behind risk prediction is, it is not sufficient to ensure risk mitigation (Mercer et al., 2009). For instance, risk warnings are accessed, interpreted and understood differently in different societies or social groups across the world (Glantz, 2009; Mercer at al., 2009). Furthermore, some individuals may not have the capacity to act, even if warnings are clearly understood.

Therefore, to ensure effective communication of risks through early warning systems, it is essential to involve their beneficiaries, the end-users of the risk alert. It is necessary to make sure they are aware of the systems existence and functioning, they have clear access to risk alerts and they interpret alerts correctly. Clear communication is a critical component to ensure adequate response from the exposed community, who are often the disaster's first victims and frequently, the first responders especially in remote areas impacted by quick onset hazards (e.g. flash floods) where it can take hours, days, or even weeks to receive support from the State or aid organizations (Glantz and Baudoin, 2014; Mercer et al., 2009).

To ensure good communication and understanding of risk alerts through early warning systems, Kellman and Glantz (2014) propose the inclusion of education as part of the early warning systems process. Educating the young can help raise awareness among vulnerable groups located

in high risk areas, as well as highlighting expected changes in risk location and frequency. This heightened awareness provides opportunities for risk preparedness and allows for community level adaption in the context of climate change.

3. Other types of Early Warning Systems

The previous section discussed the science and technology based, early warning system process, (i.e. the E2E approach) which is most commonly developed through disaster risk reduction programmes. However, there are many other types of traditional, less technology based early warning systems (Mercer et al., 2009). For instance, observations of natural climate and weather patterns have been used to predict the occurrence of natural hazards for centuries and are often used in the most remote areas of the world beyond the reach of technology based early warning systems (Basher, 2006).

Hazard prediction techniques and emergency management are remembered through stories exchanged among indigenous population (Mercer et al., 2009). Indigenous knowledge also uses a bioindicators for climate related hazard prediction, including animal and insect behaviour and plant phenology. Bioindicators can be inexpensive, locally relevant and can encourage stakeholder participation in early warning system development and maintenance. However, such indicators need to be verified and evaluated against criteria such as; specificity, variability, monotonicity, practicality and relevance. Bioindicators may not be specific to individual hazards and may provide limited advanced warning, as response often occurs after the actual onset of the hazard. Furthermore, indicators may become increasingly unreliable due to climate change itself. There is a need for a large-scale assessment of hazard bioindicators, which should also include forecasts of bioindicator change under global warming and ways to integrate bioindicators into early warning systems (Zommers, 2014).

4. Livelihood resilience and Early Warning Systems

The perception of disasters as purely natural events suggests that little can be done to avoid their negative impacts on society. However, this vision has been challenged for decades, especially in studies from social science, focusing on the notions of vulnerability and capacities (Blaikie et al., 1994). The notion of a ‘natural disaster’ fails to consider human capacity to understand risks and reduce impacts on society (Basher, 2006). The rising trend in casualties from disasters over the last 40 years is related to population growth, increased settlements in dangerous areas, environmental degradation and other societal development that have increased vulnerability. Therefore, disasters are not solely caused by the occurrence of natural hazards (Basher, 2006).

If human activities and choices influence hazard impacts on livelihoods and economic development, they can also contribute to reducing them. Communities possess resilient properties when facing hazards, including resistance and creativity: this is called “social resilience” (Maguire and Hagan, 2007). Early warning systems can enhance existing social resilience by informing at risk populations about potential changes in threats, promoting risk education, hazard detection and response plans, combining science and technology with local knowledge and experience of emergency situation and response.

Beyond the dissemination of risk alerts, early warning systems can be used as

vehicle of education, knowledge and information which are critical to resilience, especially in vulnerable areas which are at the core of the risk reduction processes. This knowledge provides coping mechanisms for short-term risk mitigation (e.g. tsunami warnings can facilitate risk communication and effective evacuation to save lives) and may facilitate risk anticipation through early identification of hazards (e.g. early signs for drought can be detected and foster preparation through food supply and storage).

This paper adopts a view of early warning systems similar to that proposed by Kellman and Glantz (2014): Early warning systems are a social process which occurs at different scales (local to national, even cross-border in some cases) and is based not only on science and technology but on discussion, communication and education with high participation and involvement of at risk communities from the onset. Moreover, early warning systems must consider the specific needs of a community in order to successfully mitigate risks and enhance resilience.

C. Case studies

The following section provides concrete examples of projects to introduce early warning systems in at risk communities. To identify those areas adopting a cross-scale participatory approach - including local communities, local and regional authorities - that combines traditional knowledge with science, finding ways to involve community members and tailoring early warning systems to their needs. The section aims to highlight the opportunities of integrating science and local knowledge, as well as explore the challenges in achieving this integration.

5. Identifying Community needs in Kenya

The most significant climatic hazards in Kenya are droughts, floods, landslides and disease outbreaks. A country assessment of Kenya by Disaster Risk Reduction Initiative Activities (DARA, 2012) shows high vulnerability to drought and moderate vulnerability to flooding. However, the frequency of these hazards and the level of damage caused are predicted to increase with climate change. DARA (2012) predicts that by 2030, Kenya will have US$5 million purchasing power parity (PPP) and US$10 million (PPP) of additional economic costs related to drought and flood, respectively. Hazard risks do not only depend on the hazard type but also on the location of the affected communities. Droughts for instance, affect approximately 70 per cent of Kenya’s land area and are most severe in the Eastern, North Eastern and Coastal provinces. Floods have been widespread in Western and Coastal provinces of the country, especially during rainy season (Senaratna et al., 2014). While several early warning systems already exist in Kenya, they are often centralized and assume a top-down approach. Flood warnings for example are sent from the Kenya Meteorological Department through the media to stakeholders (Senaratna et al., 2014). Communication gaps exist and there is a need for greater community involvement.

The CLIM-WARN project of the United Nations Environment Programme (UNEP) was launched in 2013, to identify ways to develop a multi-hazard and people-centred early warning system. Working in Kenya, Ghana and Burkina Faso, the project has conducted research on hazard risk and community vulnerability; stakeholder needs for warning dissemination; and response plans. The project’s overarching goal is to gather information to design a prototype

early warning system that could address the deficiencies in existing systems at the global scale. As part of the project, national and regional meetings were held to bring together key actors in early warning systems from government agencies or departments; intergovernmental organizations, international organizations and nongovernmental organizations; academia; and civil society. The project has documented information on the users of early warnings, the state of early warning systems in Kenya and how the to improve the delivery of climate data to users.

In addition, household surveys and focus group discussions conducted in four sites in Kenya provide detailed information on the state of vulnerability, institutional arrangements, communication and response. Three villages were sampled within each of the sites based on those perceived to be most vulnerable to hazards, determined by geographical location and the socio-economic status of individuals. In Nairobi, two peri-urban villages and an informal settlement were surveyed. In Kisumu one peri-urban village and two rural villages were surveyed, all the villages sampled in Turkana and Kwale were rural.

Surveys reveal that different communities have different livelihood profiles and consequently different community needs, which will influence the design of early warning systems. For example, sources of income vary greatly between regions: the peri-urban communities have diverse income sources. The most important sector is the retail business (e.g. shops and supermarkets) with 19 per cent of the surveyed households gaining income from this area; 17 per cent of respondents worked in the service industry; 15 per cent were involved in manual labour; 8 per cent in the transport sector (e.g. taxi drivers, *Bodabodas*); and another 8 per cent in office jobs. By contrast, agriculture is the dominant sector in Kisumu, Turkana and Kwale: 50 per cent of those households depend on farming and/or pastoralism for their livelihood.

The level of education varies from one site to the other. In Nairobi, a relatively large percentage of the population (28 per cent) have university education and only a negligible fraction does not have any form of formal education. By contrast, in Turkana County, a marginalized county in Kenya, a quarter of the population does not have any formal education and none of the respondents in the sampled villages has attained University education.

Access to information and technology also varies between communities. Individuals in Nairobi receive information through diverse channels. For instance, 93 per cent of respondents had mobile phones; 15 per cent had computers; 76 per cent had radios and 67 per cent had TV. In Kisumu, 87 per cent of the respondents had mobile phones; only 3 per cent had computers; 77 per cent had radios; and 27 per cent had TV. Turkana had the lowest record of devices, 21 per cent had mobile phones; none of the respondents had computer or TV; and only 12 per cent had a radio.

Findings indicate that some communities are likely to be more resilient to hazards than others. Households in Turkana, with only one form of income – pastoralism - may have limited options for alternative livelihood sources during droughts, reflecting a critical need for early warning systems. Furthermore, types of early warning systems must be suited to the target community. Some regions of Kenya have lower education levels and limited access to information through TV, radio, or SMS. In

these regions, traditional institutions, such as chiefs, are critical for warning delivery. In contrast, urban areas such as Nairobi may use mobile phones as an effective way to deliver warnings and spread information. Early warning systems need to flexible in design to accommodate such local differences but still ensure standard information delivery. Livelihood surveys are critical tools to identify community needs and help best design appropriate early warning systems.

6. Coupled Local Knowledge-Government Early Warning Systems in Hawaii

Rural coastal communities in the Pacific, including those in the Hawaiian islands, are at extreme risk to impacts from coastal hazards, drought and impacts from climate change (Birkmann et al., 2011), which 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 climate change risks coupled with inadequate policy and planning integration of adaptation across sectors, particularly at the community-level (HSCD, 2010). This risk necessitates the co-development of local coping and adaptation strategies, including the implementation of an early warning system that builds on, and integrates local and traditional knowledge, strategies and networks with official government early warning system mechanisms, appropriate for the spectrum of hazards prone to these communities. Insofar as, the early warning system must be developed to account for the early identification and warning of: 1) acute hazards such as tsunami and flash flooding in order to inform preparedness and response efforts to expedite evacuation and reduce loss of life and injuries; 2) chronic hazards such as, drought, sea level rise and coastal erosion in order to inform resilience-building and adaptation strategies.

To address these gaps, 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, 2013b). Through the development and support of local disaster resilience committees representing residents, businesses, governmental and non-governmental stakeholders, the project focused on participatory disaster resilience research and planning, integrating local hazard mitigation, risk reduction and climate change adaptation (Henly-Shepard et al., 2014; Henly-Shepard et al, 2015). Enhancing socio-ecological resilience and adaptive capacity necessitates a dual approach to early warning systems, including technological tools coupled with traditional and local knowledge. Research findings indicate that this integrative approach brought changes in community perceptions of early warning signs of climate change, particularly for subsistence farmers and fishermen, as well as modification in their use of this knowledge to adapt their practices.

A community vulnerability assessment culminating in a multi-sector gap analysis provided a qualitative critique of current early warning systems in place in communities, including: (1) state governmental tsunami evacuation warning sirens; (2) multi-governmental agency multi-hazard warnings via email, cellular text, radio and television; and (3) verbal informing through social networks. Verbal informing as a notification mechanism is still highly relevant and critical in rural communities, particularly for warning and evacuating persons with access and functionality needs 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 and the reduction in community ties (Henly-Shepard, 2013a; Henly-Shepard et al., 2014).

Community participants reported that the technological tools being utilized to inform acute-onset hazard early warning include tsunami evacuation warning sirens; river flood gauge monitor alerts through websites; Nextel text, email and phone alerts; and radio and television. The community disaster resilience planning project contributed to improved communication, collaboration and understanding across sectors, via reporting of community-generated expectations of and failures with these tools, resulting in expedited trouble-shooting (e.g. fixing broken sirens and improving online warning platforms). The project contributed to the creation of committee-run social media sites to share disaster information and provide grassroots early warning mechanisms. Long-term adaptation and disaster resilience planning 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 and prioritizing risk reduction strategies, policies and projects.

An in depth understanding of the local environmental context, including the cultivation and sharing of resource management knowledge and practices, is critical for environmental stewardship and continual monitoring of ecological indicators and fluxes (Tomkins and Adger, 2003). 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 (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. As a result, the disaster resilience planning project has worked to invite knowledgeable *kupuna* (elders) to share this knowledge with the committee and the community at large. Traditional subsistence fishing and farming still exist in some of the case study communities; this creates a duality of improved social capacity and place-based resource management, whilst also creating vulnerability from overdependence on resources which may be impacted by climate change and disasters (Tomkins and Adger, 2003). In support of this coupled technological-traditional knowledge approach and to identify threats quickly and promote long-term adaptation, 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; (3) improved coping and adaptive capacity through training, resource access and the regeneration of social networks.

7. Early Warning Systems in Sri Lanka

Sri Lanka is a lower middle-income country with a total population of 20,277,597. Research states that 33 per cent of the Sri Lankan population are engaged in climate sensitive livelihoods including, agriculture (rice, tea, rubber and coconut cultivation) and fisheries related livelihood activities. In

addition, 25 per cent of Sri Lanka's population live in coastal areas. Coastal communities both rural and urban, are at risk of sea level rise, increasing temperatures, disasters and other issues, such as salt water intrusion (Jayatilleke, 2008). 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 temperature and unpredictable monsoon rains); health; and geographic locations such as the coastal belt. Tourism, fisheries and agriculture play a substantial role in livelihoods of coastal communities and are directly or indirectly exposed to coastal vulnerability. These threats impact the national economy, social stability, human health and even national security.

An estimated 2-3 million Sri Lankan people who mainly live 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). Localized flood and landslide disasters in January 2007 and the 2004 tsunami, indicate that communities need more capacity to prevent death and destruction from hazards and disasters.

In 2009, as a pilot project to reduce landslide risk, a number of community based early warning systems were introduced in selected landslide prone areas in the Matale district. Communities were educated on evacuation paths, engaged in evacuation drills in an emergency situation and were at the core of the early warning process. Fibreglass rain gauges were introduced in the communities as an early warning system (Wijesinghe, 2014). Identified observers were educated on how to measure the portable plastic rain gauges which were marked by different colours, observers had the responsibility of daily monitoring of the rain gauges and verbally informing the surrounding households on the status, ensuring clear and consistent communication to all at risk. For instance, if the water level reaches between 75-100 mm (green colour) the community members will be alerted, a warning will be issued if it continues to rain and the water level reaches over 100mm (yellow). Continual rain for the last 24 hours and a water level reading of over 150mm (red) will result in an evacuation. Between October and November 2010, 121 families used this method to evacuate to safer places. The method was also tested in the Nuwaraeliya district in 2011. Active community involvement for a longer period of time in community based early warning systems is essential but is difficult to ensure, this challenge needs to be overcome to secure the livelihoods of hazard prone communities.

This project demonstrates the importance of community-based early warning systems in areas like Sri Lanka, where 10 per cent of people live in remote rural areas, beyond the reach of communication on hazard and early warning alerts. Community members should be important partners in the implementation of such systems which are necessary to quickly disseminate alerts in remote areas and enable a community to react to warnings, to protect their livelihoods and lives. Yet, as of today, there are very few national and international level non-governmental organizations actively engaged in community based early warning systems. A few examples of ongoing projects include; Sri Lanka Red Cross Society (SLRCS) which assists early warning dissemination to communities through its 26 branches and volunteer network; Practical Action, which compiles data on community based systems and provides technological solutions including rainwater harvesting in drought prone areas,

strengthening local capacity for mitigation (UNDP, 2009); LIRNEasia, a regional ICT policy and regulation capacity building organization, with a disaster warning and ICT programme (Gow et al., 2007; Waidyanatha et al., 2008), which has established Community Disaster Management Centres in target villages. These initiatives reduce panic and chaos in a major disaster; however, more participatory community work involving all actors is needed to secure livelihoods and lives from natural hazards. In the future, vulnerability studies and mapping should also try to incorporate slow-onset disaster impacts such as droughts, as their occurrence and intensity is expected to increase with climate change. On top of quick-onset hazards like Tsunami, slow-onset events also substantively affect livelihood conditions, increasing risks for food insecurity and famine, for instance.

D. Discussion: building cross-scale integrative Early Warning Systems for livelihood resilience

Early warning systems for natural hazards are a vital infrastructure for society. Their main objective is to empower communities to make decisions to ensure their safety and protection. Early warning systems for natural hazards provide citizens with a sense of security (Samarajiva et al., 2005). Yet, Maskrey (1997, p. 22) stated that "EWS are only as good as their weakest link. They can, and frequently do, fail for a number of reasons". Communication is one of the most important links of the chain and failure to communicate correctly can lead to disastrous impacts, as observed for example, through the increased food insecurity following the drought in the Horn of Africa in 2010-2011 (UNISDR, 2012), and through the heavy human and infrastructure losses following Hurricane Katrina in New Orleans in 2005.

Scholars advocate placing the community at risk at the core of early warning systems, as the main drivers of the risk management process (Glantz and Baudoin, 2014; Hall, 2007; Kellman and Glantz, 2014). The case studies provided in this paper describe attempts to do this - with limited successes so far. One of the challenges raised in the Sri Lankan case study is the difficulty to maintain community involvement in early warning systems, especially in the long term. The Hawaiian case study highlights the erosion of traditional emergency management knowledge. Finally, the Kenyan case study highlights the diverse needs of communities within one country, providing warning services of similar standard across a diverse country poses a governance challenge with potentially large financial costs.

A potential solution to these challenges is that those communities at risk drive the conceptualization and application of early warning systems. Involvement, from the onset, of local actors will not only contribute to improved warnings that are contextually appropriate to the community (i.e. warnings are received and understood by all), but will also ensure that early warning systems match local need. Furthermore, it is a great opportunity for knowledge exchange on risk detection between communities living alongside disaster risks and the scientific community (Kellman and Glantz, 2014). As stated by Hall (2007), early warning systems are an extension of existing risk management practices, often embedded in indigenous knowledge and therefore, those with firsthand contextual experience should be leading the process.

Communities around the world use various sources of information to develop their own warning systems (Maguire and Hagan, 2007). These traditional sources of information are sometimes trusted by the community over scientific data, as such, grass-root knowledge cannot be neglected while building early warning systems; rather it should be combined with science and technology to augment and confirm risk prediction (Hall, 2007). Valuing local observations also builds trust among at risk communities and practitioners. Indigenous knowledge provides a wealth of possible bioindicators for climate related hazards. Bioindicators, such as animal and insect behaviour and plant phenology, can be easy and inexpensive to monitor, are locally relevant and can encourage stakeholder participation in early warning system development and maintenance. However, as mentioned earlier, acute evaluation of the bioindicators is required to assess their relevance and specificity for a given hazards. The time lag between the detection of a risk and its actual occurrence, offered by these indicators, is also an issue to keep in mind when assessing bioindicators' relevance (Zommers, 2014).

New technological tools can also be used to involve community members in early warning systems. Social media and community disaster mapping have been used in post disaster response and may have a role to play in early warning systems. In areas of the world where there is a surge in mobile phone growth and open source data collection, communities can be involved in monitoring prior to warning dissemination (Senaratna et al., 2014). Ultimately, science and technology can improve early warning systems when combined with local knowledge. Cross-scale integration also means that early warning systems are using local means of transmission in order to ensure clear and tangible communication on risks, understood by all and disseminated as widely as possible among communities.

As a social process, early warning systems are much more than just risk detection and alert dissemination, they also include raising awareness. At risk communities should be informed about risks in their area, the role of an early warning system and the potential shortcomings of warning systems. Current science on risk and hazard detection is not flawless and this should be clearly explained because an informed community will be more inclined to understand and accept false alarms, without discrediting scientists (Hall, 2007). To build respectful relationships between practitioners and the community, local knowledge, experience and histories of emergency management must be respected and included when informing at-risk society, as they are relevant to risk understanding and emergency actions. Transmission of traditional knowledge through education programmes will also help to preserve the knowledge and ensure those carrying this knowledge feel valued in the early warning process. For these reasons, educational and informative process within early warning systems should not be driven by scientists and risk managers but by key community members.

Communities at risk must be given the capacities to face risks (e.g. knowledge and response options). In this context, early warning systems could be considered as capability tools, in other words, they could be used to foster capacity building among the local communities located in areas prone to natural and climate risks (Hall, 2007). A pathway to ensure early warning systems contribute to enhance livelihood resilience would be to promote risk education through the EWS process. Raising awareness on natural and climate risks, informing on

potential indicators to detect such risks, and on options that are available when a hazard occurs (e.g. where shelters are located in case of a Tsunami) will contribute to strengthen preparedness at the local level. These informative sessions could be developed at school, for instance, so to raise awareness among the youngest and ensure that risk preparedness becomes well rooted in a given community. It is also a way to get children familiar with the EWS, to accept them as part of their daily life and to give them the tools to understand and respond to alerts (Kellman and Glantz, 2014).

This paper argues against the E2E linear paradigm for early warning, where one-way information flows in a singular direction from scientists to the at risk community, and instead argues for the placement of local community at the core of early warning systems. E2E early warning systems provide neither a feedback loop from warning recipients to warning issuers; nor does it allow for recipient participation in the risk detection and communication process. Viewing early warning systems as social processes embedded into a local community requires rethinking the way early warning systems are conceptualized: from merely alert systems to a 'resilience enhancer', a process which reduces local vulnerability to multiple risks (Kellman and Glantz, 2014). A new notion of early warning systems, however, raises some challenges which are discussed below.

E. Conclusions and moving forward

Early warning systems can enhance livelihood resilience and are important tools for relevant decision-making in the face of extreme climate and natural events. This paper argues in favour of early warning systems that are both technically systematic and people-centred, an idea supported by Basher (2006). We also discuss new opportunities in the field of risk reduction by integrating indigenous, traditional knowledge, experience and history on hazards and risks detection and management alongside the scientific approach that currently drives this field of activity.

However, an "End-to-End-to-End (E-to-E-to-E)" model - a cross-scale approach that integrates feedback loops and knowledge from the grass-root level while ensuring long-term community participation, raises many challenges, some of which were highlighted in the case studies in this paper. For instance, sustaining community involvement may be a challenge. Civil society failures within communities may make it difficult for different groups to be involved in, or benefit from community participation (Mansuri and Rao, 2013). As a result, not all forms of participation will have the same development outcomes and positively influence inclusion and social cohesion. Other questions raised include; how to combine relevant science, technology and local knowledge; how to build trust among experts and users of the early warnings; how to create a sense of ownership among early warning systems beneficiaries. These questions are of great interest as an integrated early warning system would provide a real opportunity to foster livelihood resilience at the local level in the face of a changing climate.

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Livelihoods are the lattice upon which all human organization hangs, and some of the worst-case scenarios of global change – displacement, migration, conflict and famine – all centrally concern the problems that people face in sustaining productive livelihoods.

The 2013-2014 Resilience Academy is a group of 25 international researchers and practitioners who have recognized that dangerous global change is a threat to the livelihood systems of the world's poor. The Academy met twice, in Bangladesh and Munich, Germany, and developed a set of working papers as an evidence base for the concepts and practices that we, as a cohort of colleagues, propose for addressing this pressing challenge.