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Social innovations and drivers in flood early warning systems: A community-based transboundary perspective from Elegu flood plain in Northern Uganda

Vincent Canwat

Department of Development Studies, Faculty of Business and Development Studies, Gulu University, Gulu, Uganda

Correspondence
Vincent Canwat, Department of Development Studies, Faculty of Business and Development Studies, Gulu University, P.O. Box 166, Gulu, Uganda.
Email: v.canwat@gu.ac.ug

Abstract

Early warning systems play significant roles in disaster risk reduction and management. However, a global picture of how they function on the ground, especially in developing countries, is lacking. This study assessed social innovations and drivers in the community-based transboundary flood early warning systems in the Ugandan context. The study found that the community-based transboundary flood early warning system generated three social innovations: new inter-community relations, new community-local resource relations, and new housing and bedding structures. New inter-community relations were driven by the transboundary nature of the flood and kinship. New community-local resource relations were driven by the lack of government support for the early warning system. New housing and bedding structures were driven by the uncertainty about the flood at night. The study confirms the importance of social market failure in driving social innovations and the role of community-based flood early warning systems in promoting the utilisation of local resources. The effectiveness of transboundary early warning systems in extending lead time and reducing losses was also confirmed. However, the early warning system was found to be effective only during day time. The study, therefore, recommends government intervention in bridging the early warning system gap by installing telemetry.

KEYWORDS

community-based early warning system, early warning systems, Elegu Flood Plain, flood, GIS, Social innovations, transboundary early warning system, Uganda

1 | INTRODUCTION

Floods are one of the major hazards. They cause most of the water-related disasters that globally account for 90% of all disasters associated with natural hazards and result in thousands of mortalities and billion-dollar losses annually (Perera et al., 2019). Early warning systems (EWS) are adopted as one of the flood risk management measures. An EWS is "an integrated system of hazard monitoring, forecasting and prediction, disaster risk

assessment, communication, and preparedness activities systems and processes that enable individuals, communities, governments, businesses, and others to take timely actions to reduce disaster risks in advance of hazardous events" (UNDRR, 2017).

EWS are largely techno-centric and top-down in nature. The techno-centric, top-down EWS has a linear chain from the risk diagnosis to the dissemination of alerts to vulnerable groups and a centralized management by regional or national meteorological or geological services providing risk prediction and warning issuance (Baudoin et al., 2016). The chain has no direct engagement with the recipients of early warnings (Baudoin & Wolde-Georgis, 2015; Glantz & Baudoin, 2014), but strong technological links (risk detection and monitoring) whereas its societal components (communication and response capability) are the weak links (Baudoin et al., 2016). People are only included as receivers of alerts (Marchezini, 2020).

The techno-centric top-down EWS is centralized and ineffective in responding to the needs of peripheral and vulnerable populations (Zia & Wagner, 2015). Such weaknesses in the service delivery often trigger social innovations. Following from Howaldt et al. (2015) and Caulier-Grice et al. (2012), social innovation is defined in this paper as new ideas, concepts, actions, frames, models, methods, systems, processes, products, services, markets, rules and regulations, policy, form of cooperation and organisation, and institutional arrangements that meet social needs and challenges in a better way than existing practices. Social innovations arise to address social market failures (Moulaert et al., 2013; Nicholls et al., 2015).

Social innovations in flood early warning system (FEWS) include community-based FEWS (CB- FEWS) and community-based transboundary FEWS (CB-TB-FEWS). A CB-FEWS refers to an integrated system of tools and plans managed by and for communities, providing real-time flood warnings to reduce flood risks (Bhatt, 2019a). The CB-TB-FEWS integrates a CB-FEWS and TB-FEWS. In CB-TB-FEWS, upstream communities detect flood risk and disseminate the information to vulnerable downstream communities located across the border, providing them sufficient lead time for preparedness (Pradhan & Pandey, 2019).

Early warning systems play significant roles in disaster risk management. They save lives and reduce economic losses from hazards (Kafle, 2017; Perera et al., 2019). They also reduce post-disaster rehabilitation and rebuilding costs; improve intra and inter community networks and facilitate climate change adaptation and resilience (Bertule et al., 2018). Although the ability of EWS to reduce flood risks is widely acknowledged (Pappenberger et al., 2015; Thielen-del Pozo et al., 2015), a global picture of how they function on the ground, especially in the developing world, is lacking (Perera et al., 2019). This paper contributes to bridging this gap. The aim of this paper is to assess social innovations and drivers in the community-based transboundary flood early warning system. In this study, the national boundary concept is expanded to the sub-national boundaries. The subsequent sections cover a review of social innovations generally and in the FEWS, methods, results, discussion and conclusion and recommendation.

2 | LITERATURE REVIEW OF SOCIAL INNOVATIONS

2.1 | Characteristics and dimensions of social innovations

Social innovations have three main characteristics. They are new combinations or hybrids of existing elements, but not wholly new in themselves; their implementation cuts across organisational, sectoral and disciplinary boundaries; and they create new social relationships between previously separate individuals and groups which matter to the people involved, contribute to the diffusion and embedding of the innovation, and promote further innovations (Mulgan et al., 2007). These features set social innovations apart from other innovation types.

There are also two dimensions of social innovations: new social processes or new social outcomes. As new social processes, social innovations are viewed as changes in social relations, but as new social outputs and outcomes, they are considered as solutions to social market failures in the provision of vital public goods (Nicholls et al., 2015). The process dimension of social innovation stresses the idea that not only the solutions but also the process to arrive at these solutions matters. For example, the process need to be collaborative and participative (BEPA, 2011). In the outcome dimension, BEPA distinguish three different approaches: narrow focus on social demands of vulnerable groups that are currently unmet, broader focus on challenges of society as a whole, and concerns with systemic reforms of societal configurations, which lead to an increase in overall well-being. Dimensions of social innovations can also be categorized into three: content/product/outcome dimension focusing on the satisfaction of human needs, process dimension concerned with changes in social relations and governance, and empowerment dimension focusing on increasing socio-political capability (Rüede and Lurtz, 2012).

2.2 | Types of social innovations

Social innovations can be incremental, institutional or disruptive innovations. The incremental social innovations include newer tools and techniques used for monitoring and communicating flood risks. For example, a telemetric system, which relays real-time early warning to provide sufficient lead time for preparedness (Pradhan & Pandey, 2019; Prakash, 2019). While incremental social innovations focus on goods and services, institutional social innovations focus on the market and seek to harness or retool existing social and economic structures to generate new social value and outcomes (Nicholls and Murdock, 2012; Nicholls and Opal, 2005). They include the creation of new relations. The disruptive social innovations aims at systems change and their drivers are social movements and self-consciously political actors and networks aiming to change power relations, alter social hierarchies and reframe issues to the benefit of otherwise disenfranchised groups (Nicholls and Murdock, 2012; Nicholls et al., 2015). This includes new networks advocating for change in handling warning systems.

2.3 | Drivers of social innovations

What drives social innovations can be explained by the outcome-driven model, partnership model and resilience theory. The outcome-driven model views social innovations as driven by the need to address social market failures. Here, market failures are conceived of as failures not only in commercial markets but also in public sector markets, where the state fails to provide public goods, and civil society markets, where not-for-profits fail to provide effective goods and services to their beneficiaries (Nicholls, 2008). Social innovations then become responses to unsatisfactory solutions in the public and private sector or the failure of established systems to deliver well-being and economic prosperity (Moulaert et al., 2013; Nicholls et al., 2015).

In the new partnership model, social innovations are viewed as driven by the realisation that partnership with private and civil society actors improves the efficiency and effectiveness of public services. Social innovations are encouraged to reinvent government (Osborne and Gaebler, 1992). A variant of the partnership model also considers social innovations as a necessary companion to rapid technological change and economic innovation because the innovations reshape social relations to maximise productivity and economic development (Hämäläinen, 2007). Here, social entrepreneurship reconciles a historical division between private and public sector mechanisms of productivity growth (Drayton, 2002).

The resilience theory traces social innovation origins to the need to strengthen social and ecological resilience against challenges confronting economic, social, cultural, and political institutions (Westley, 2008). For Cahill (2010), resilience is an indicator of system's ability to confront and adapt to challenges or risks that could derail a system. It is also the capability to stabilize and adapt within a constantly changing operating environment (Pinsent, 2012).

2.4 | Strengths and weaknesses of social innovations

Social innovations have many advantages. They offer valuable solutions to localised and complex problems, social market failures and more systemic and structural issues (Nicholls et al., 2015). They also broaden the discourse of development and innovation by bypassing or confronting dominating paradigm of market-based development and market-oriented innovations; fostering debates about approaches and coping strategies addressing inclusive development challenges; and offering opportunity for promoting change as their process relies on interplay and contagion across domains, logics and multiple levels (Brandsen et al., 2016). However, the normative assumptions that portray social innovation as an unproblematic and consistently positive phenomenon without drawbacks or unintended consequences are questionable because of the following reasons.

Firstly, social innovations addressing public welfare issues and driving political change face challenges of democratic and public legitimacy. Their democratic legitimacy problem arises because they confront strong vested interests and entail private actions (Nicholls et al., 2015) and their public legitimacy is compromised by forces that view their hybrid and contradictory logics and models as attempts to privatise the social, dismantle the state or undermine civil society (Nicholls and Cho, 2006; Nicholls et al., 2015; Suchman, 1995). Secondly, social innovations face challenges of scaling up and accessing commercial finance. While scaling up is hampered by the resource-intensiveness of the innovation, limited access to commercial finance is attributed to difficulties of assessing its risk and return using the conventional financial measures, its social focus that make it unable to maximize financial resources and the lack of fully functioning market for investing social innovation (Nicholls et al., 2015). Thirdly, Nicholls et al. criticised social innovations for excluding some groups from receiving social goods and services; exploiting and privatizing the social because of the high interest rates of many micro-finance institutions and their blending of social and financial objectives; and their possibility of being hijacked for socially divisive or

destructive objectives. Lastly, Brandsen et al. (2016) argue that most local social innovations are precarious because they remain local and last for shorter time; their innovators often pay little attention for diffusing them; the majority of them have aims and practices that are highly controversial or even viewed as threatening rather than promising and they are often misrepresented as being similar to business innovations.

2.4.1 | Implications of social innovations for private, public or non-profit sector

Social innovation is relevant across sectors. In the private commercial sector, social innovation is a source of a model for new roles of business in society (Nicholls et al., 2015). Here, the innovation entails solving social problems with business skills and methods (Bessant et al., 2011). It involves developing innovative solutions to overcome market failures (Kacou, 2011; Murray et al., 2010; Saul, 2011), using community needs as an opportunity for business solutions (Rüede and Lurtz, 2012; Saul, 2011) or using inclusive economic-oriented approach to address the needs and capacities of low-income populations (Borger et al., 2010; Kacou, 2011).

For the state, social innovation reflects traditions of welfare reform for increased efficiency and effectiveness and a move from a focus on New Public Management to Public Value and New Public Governance.[1] It seeks to transform the power structures across social relations that allocate goods and services ineffectively or unequally (Nicholls et al., 2015). Governments generate social innovations to address systemic, social, economic, and environmental challenges affecting public service delivery (Staszowski et al., 2016). For Staszowski et al. associate these innovations with new forms of collaboration that involve more participatory, horizontal practices such as co-governance, co-design, co-production, and peer-to-peer production of public services.

For civil society, social innovation may involve both internal processes of organisational change (like new legal forms, collaborations and income strategies) and novelty in external outputs and outcomes (such as new products and services).[2] In the context of civil society as the third sector, social innovations have different origins such as social movements, non-profit organizations and citizen-based approaches of organizing life on a local level.[3]

2.5 | Social innovations in early warning systems

Social innovations in flood risk management address social challenges and provide social benefits related to flood risk. These innovations reduce personal injury, loss of life, damage to property and improve community resilience. Social innovations in EWS are largely bottom-up and people-centred. In the bottom-up EWS, the whole process is initiated, driven and controlled by its beneficiaries (Baudoin et al., 2016) and disaggregated communities are integrated with local knowledge (Zia & Wagner, 2015). A people-centred early warning systems (PEWS) seeks to "empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life and damage to property and the environment" (UNISDR, 2006). It places the affected people at center stage and recognizes their role in reducing their vulnerability to the hazards they face (Marchezini, 2020; Zhang et al., 2020). PEWS empowers local people and builds local resilience to disasters by helping communities to better help themselves manage local risks (Jones et al., 2013).

PEWS have four elements: risk knowledge, risk monitoring and warning service, risk communication and dissemination and response capability (UNISDR, 2006). Figure 1 presents details of the elements. PEWS address all elements to ensure timely, accurate, reliable, and understandable information rightly reaches everyone for them to act (Practical Action, 2020).

2.6 | Community-based flood early warning system (CB-FEWS)

A CB-FEWS is an integrated system of tools and plans managed by and for communities, providing real-time flood warnings to reduce flood risks (Bhatt, 2019a). It is also a "system developed, managed and maintained by the community with external support limited to facilitating active and meaningful participation of all community members" (Mercy Corps and Practical Action 2010). In a CB-FEWS, the "communities are active participants not

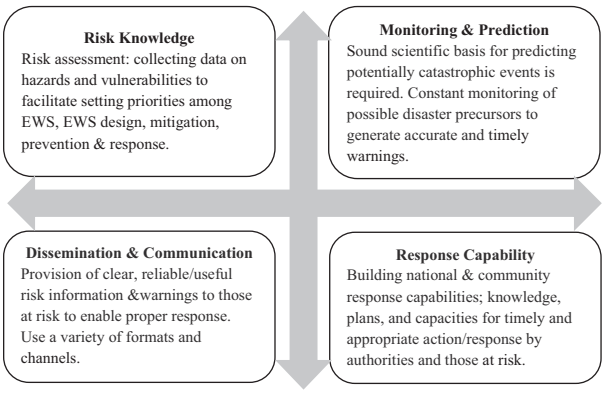

FIGURE 1 Elements of warning systems.

just in the design but also in the ongoing monitoring and management" (Smith et al., 2017, p. 425).

CB-FEWS are more relevant for developing countries where government capacity and resources are limited. They ensure community sustainability and empowerment because the systems are mostly monitored by the community members (Khan et al., 2018). Khan et al. also credit them for being more effective in meeting local needs for the disaster preparedness and response because they acknowledge that the first response to a disaster always comes from the community itself and that in many cases, top-down and highly technical approaches fail to address the specific needs of vulnerable communities, ignoring the potentials of local resources and capacities. They also argue that the EWS help communities use local resources and capacities effectively to better prepare for and respond to disasters and adopt measures to reduce their vulnerability.

While CB-FEWS have many advantages, they are not without limitations. They rely on real-time water level readings, yet both automatic and manual systems are susceptible to failure during extreme rainfall events and their lead times are short, especially in mountainous catchments where rivers convey water rapidly (Zurich, 2015). Gladfelter (2018, p. 2) also argues that the celebrated CB-FEWS discourse of mobilizing resilience by building people's capacity to take action on their own can disregard and even reproduce underlying patterns of vulnerability if the systems "ignore the social and political dimensions of vulnerability and do not balance the demands they make of communities with equal efforts to hold governments accountable for protecting their citizens". Gladfelter observed that empowering people to secure themselves can shift the burden of disseminating early warnings from the government onto residents. Evans and Reid (2014) argues that the CB-FEWS' suggestion that "people can be capable, resilient and able to protect themselves" and, "not see themselves as victims" (Mercy Corps and Practical Action, 2010, pp. 9, 43) encourage the at-risk community not to question or resist the structures that have made them precarious, but rather to become resilient within them instead.

2.7 | Transboundary flood early warning system

Transboundary FEWS (TB-FEWS) are prevalent in river basins prone to flood risks. In TB-FEWS, the upstream and downstream components are located across the border. It understands and establishes upstream-downstream linkages as the biophysical and socio-economic conditions upstream affect conditions downstream (Gupta et al., 2021; Mehta and Warner, 2022).

Social innovations in TB-FEWS are technological and institutional in nature. The technological components include Flood Guard installed between Bulgaria and Greece (INTERREG Greece–Bulgaria, 2019), software and web platforms established for flood forecasting in the cross-border region between Bulgaria and Turkey (Phare MRDPW, 2021) and embankments constructed along the Koshi River across India-Nepal border. The institutional social innovations involve new relations comprising state-to-state and community-to-community interactions for flood risk management. For example, collaboration between Bulgaria, Turkey and Greece to mitigate flood problems in the Maritsa Basin where bilateral agreements were established between the countries regarding information exchange for the forecast systems (Mehta and Warner, 2022) and India–Nepal Joint Committee on Inundation and Flood Management.

TB-FEWS can be state-centric (state-driven) or community-centric (community-driven). The community-centric TB-FEWS are community-based. Generally, TB-FEWS are very effective in saving lives and reducing damage, but they work well when they are community-based (Bhatt, 2019a). A community-based TB-FEWS (CB-TB-FEWS) integrates a CB-FEWS and TB-FEWS. In the CB-TB-FEWS, upstream communities detect flood risk and disseminate the information to vulnerable downstream communities located across the border, providing them sufficient lead time for preparedness (Pradhan & Pandey, 2019). CB-TB-FEWS are more effective than state-centric TB-FEWS in minimising cost, integrating local knowledge, responding faster to the different needs at the local level and saving people's lives and livelihoods (Gupta et al., 2021 Molden et al., 2017; Shrestha, 2017). However, they are prone to financial constraint and local political and religious complexities (Gupta et al., 2021). For example, social vulnerability to floods is associated with caste and social deprivations in flood-prone areas of India and Nepal (Acharya and Prakash, 2019; Jha and Gundimeda, 2019; Pritchard and Thielemans, 2014).

While national-level policies and transboundary collaboration create an enabling environment to improve flood management at the local level, the state-centric TB-FEWS significantly suffer from political factors and lack much faster responses to the different needs at the local level (Gupta et al., 2021). The political nature of Transboundary Rivers tends to compromise the effectiveness of TB-FEWS. This is because the river's transboundary nature brings into play multi-level and multi-scale actors with varying perspectives and interests that reflect the contrasting (geo) political and socio-economic contexts and priorities (Bakker, 2009; Wolf, 2007). Particularly, Zeitoun and Warner (2006) noted the role of power relations, as power and its usage, which tend to affect the

outcomes of transboundary interactions and governance. Mehta and Warner (2022) also attributed poor access to information on the dams and the river required for the flood forecasting and early warning systems and emergency response to the partial sharing of information by the Bulgarians, generating distrust amongst the riparian countries, namely: Bulgaria, Turkey and Greece. This problem tends to be associated with the securitization of water management and borders. For examples, the integration of water management and early warning systems information into military institutions in Turkey and heavy securitization of borders in Greece and Turkey (Mehta and Warner, 2022) and the treatment of hydrological data regarding Transboundary Rivers as classified information in India (Gupta et al., 2021). While water cooperation exists between India and Nepal, Gupta et al. argue that this cooperation is the consequence of hydrohegemony rather than mutuality.

3 | METHODS

The study took place in Elegu Town Council and the catchment area of River Unyama. As Figure 1 shows, the Town Council is situated along the Uganda-South Sudan border in Amuru District, Northern Uganda. It lies in lowland along River Unyama, which floods Elegu following heavy rainfall in its catchment area. Table 1 shows that the flooding occurs after every year. It happens when the River overflows its banks, spilling out water into adjacent low-lying, dry land.

The flooding covers nearly the whole of Elegu Town Council. Being a commercial border town, the flooding causes huge economic losses. Because of the high flood risk and losses, there arose the need for an early warning system to reduce the losses arising from the flood.

TABLE 1 Frequency of flooding in Elegu Town Council.

Year	Frequency of flooding	Severity of flooding
2013	3	Severe
2014	0	Insignificant
2015	5	Severe
2016	0	Insignificant
2017	3	Very severe
2018	4	Less severe
2019	0	Insignificant
2020	16	Severe
2021	0	Insignificant

Note: Field interview with Chairman of Elegu Town Council.

The study used a simple random and purposive sampling. While the random sampling targeted community members, the purposive sampling engaged the local leaders who are always involved in the flood risk management activities in the Town Council. In the simple random sampling, the second nearest household or shop from the previous respondent was always chosen.

In total 24 respondents were interviewed with 16 respondents being community members, five respondents being elected leaders (local council members) and three respondents being government staff (Police officer, Environment Officer, Parish Chief). The respondents were interviewed using interview guides to generate qualitative data. More open-ended questions were asked to facilitate discussion with respondents. Leading questions asked were related to: causes, frequency and impacts of floods, sources of early warning and the lead time, how the earning warning system (EWS) is organised and operated and the response process and capacity. GPS coordinates were also generated from Elegu Town Council and the catchment area of River Unyama to generate a map that illustrates the upstream and downstream parts of the EWS.

Collected data were subjected to different treatments. The GPS coordinates were used to generate a map that illustrates the study area and risk monitoring points. Text data were coded summarised using descriptive statistics and presented in tables. Coding was done because it eases data analysis and summary of results, ensures validity (coherence between the objective and the results) and promotes transparency (Linneberg & Korsgaard, 2019).

4 | RESULTS

4.1 | Flood early warning system in Elegu Town Council

Interactions with local leaders in Elegu Town Council revealed that no early warning system (EWS) existed in the Town Council before 2013 because flood was not a problem. While the area had a history of flooding, people were not exposed to it. This is because the border area where the Town Council is situated used to be an Elephant corridor and a hunting area with no settlement and commercial activities. However, when the immigration office was established in the area in 2012, settlement and commercial activities began in 2013, people and businesses became exposed and vulnerable to flood and the need for a EWS arose. The current EWS is, therefore, an innovation because it is a new practice or system in the area.

An early warning system (EWS) for Elegu flooding is a community-based transboundary EWS because flood monitoring and communication mainly occur in upstream communities, which are located outside the subcounty where flooding occurs. Table 2 and Figure 2 show that flood risk knowledge is acquired at points A, B, and C. When it rains for 3 days consecutively in places around Gulu (point C), there is often a high likelihood of flooding in Elegu Town Council (point D). The possibility of flooding is also monitored from the bridge at point B and a tributary of River Unyama at point A, which are, respectively, 42 and 15 km away from point D.

According to the Chairman Local Council III of Elegu Town Council, risk communication starts and occurs at points A, B, and C. When it rains for 3 days consecutively in places around Gulu and the water level reaches the bridge, the upstream communities inform their relatives and local leaders in the flood-prone area of Elegu about the high risk of flooding. Upon receiving information about the raised water level and the prolonged rainfall upstream, the local leaders start monitoring the water level from the tributary of River Unyama (point A). Details of the chain of these early warning system activities are presented in Figure 3.

When the tributary of the River Unyama is filled up with water, the local leaders alert the residents of the Town Council by announcing the impending flood using a megaphone for the local church and by sounding an alarm from the police fire brigade vehicle. Local leaders also move around the Town Council alerting people using megaphones. People are informed about the impending flooding and advised to move to safer places. Risk communication from points C to D, B to D and A to D take place on mobile phones.

Risk communication paves way for the response, which greatly depends on the response capability. Elegu Town Council has no special response infrastructure. Residents depend on locally available resources. Table 2 shows that residents of Elegu Town Council respond to flood risk by taking refuge at the high-built Gulu-Nimule highway and the border custom premises.

TABLE 2 Descriptive statistics on Elegu early warning system.

Variable	Frequency	Sample size
The flood caused by River Unyama	21	21
Government supports FEWS	0	14
The government provides post-flood relief support	14	14
Received flood warning from Attiak	10	20
Received flood warning from Attiak and Gulu	5	20
Received flood warning from Gulu	5	20
Received flood warning from relatives	6	20
Received flood warning from local leaders	3	20
Respond to flood by moving to Gulu-Nimule Highway	10	19
Respond to flood by moving to the Highway and Elegu-Border Custom	02	19
Respond to floods by moving to safer places	02	19
	Mean	Sample size
Early warning lead time	6.45	11

4.2 | Social innovations in Elegu flood early warning system

4.2.1 | New downstream-upstream relations

The Elegu flood early warning system created new relations between downstream and upstream communities. Table 2 shows that downstream (flood-affected) communities receive flood risk warning information from either relatives or local leaders in upstream communities. Therefore, the new downstream-upstream relations fall into two categories: interactions between community leaders and relations between community members. No direct relation existed between downstream and upstream community leaders before the establishment of a Town Council in Elegu. However, upon the establishment of the Town Council in the area, floods became a recurrent problem and downstream leaders created new relations with upstream leaders as a means of facilitating flood risk monitoring and communication.

Although prior direct interactions existed between downstream and upstream community members before the relocation of the Town Council to Elegu, the relations constituted only business transactions and family relationships. However, the establishment of the Town Council in the flood-prone areas deepened communications between downstream and upstream community members. While previous interactions targeted only business partners and relatives, the flood risk communication is directed to the entire community in Elegu Town Council.

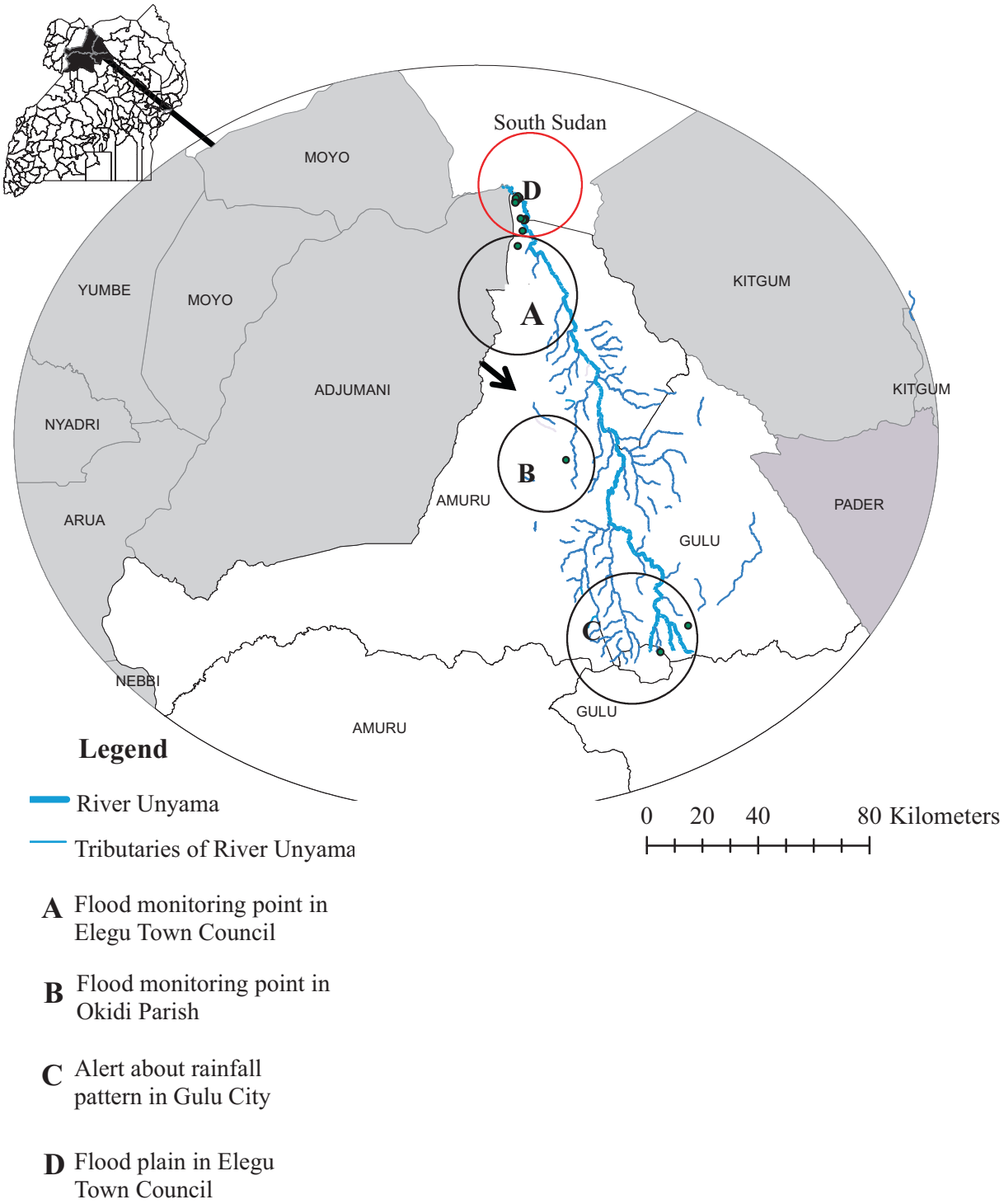

FIGURE 2 Elegu flood plain and River Unyama catchment area.

4.2.2 | New community-local resource relations

The Elegu flood early warning system created new relations between the community and local resources, notably: Unyama Bridge in Attiak, River Unyama tributary, Gulu-Nimule Highway and Elegu-Border Custom. As the Chairman Local Council III of Elegu Town Council noted, "When the water level reaches River Unyama Bridge in Okidi Parish, monitoring water level from the tributary of River Unyama starts and when the tributary is full then residents of Elegu Town Council are alerted

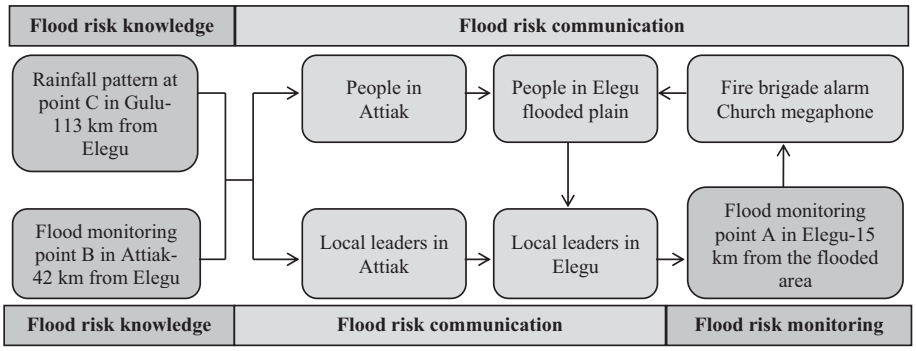

FIGURE 3 The chain of early warning activities in River Unyama catchment.

to move to Gulu-Nimule Highway". Table 2 also confirms the usage of this early warning information channel because the channel is used by local leaders.

Therefore, in addition to aiding transport and linkages across River Unyama, the bridge facilitates flood risk monitoring, predicting, and communicating flood risk. The bridge provides a threshold for determining whether communicate a flood risk warning or not because the communication of a flood warning is only made when the water level in Unyama River reaches the bridge. This is equally true with the River Unyama tributary. The tributary also serves as a threshold for flood risk communication because the residents of Elegu Town Council are provided with the flood risk warning only when the tributary is filled up with overflow from River Unyama.

For Gulu-Nimule Highway and Elegu-Border Custom, Table 2 shows that they are destinations for those seeking refuge from the flood. So, the highway is not just a transport infrastructure, but also a flood response infrastructure. Equally, the Elegu-Border Custom is not only a revenue collection point but also a flood response infrastructure. Community members take refuge and bring their vehicles and other properties to the Gulu-Nimule highwayat the Elegu-Border Custom because they are so raised that flood water does not submerge them.

The Elegu flood early warning system (FEWS) relies significantly upon local resources. Besides their original roles, the resources also serve as a threshold for risk communication and a flood risk response infrastructure. Therefore, the Elegu FEWS infuses new values into local resources.

4.2.3 | New housing and bedding structures

Because of the risk or possibility of flooding at night, new housing and bedding structures emerged. Some residents construct houses standing over 1 m above the ground. Others construct raised bedding structures using locally available wooden materials. The new housing structures were personally observed and the bedding structures were confirmed by the local leaders in the flood-affected community. These structures prevent community members from being swallowed by water when sleeping. Some community members relocated to new areas, especially the part of the Town Council less or not affected by flooding.

4.3 | Drivers of Social innovations in Elegu flood early warning system

4.3.1 | Drivers of new inter-community relations

Downstream-upstream relations were driven by kinship and the transboundary nature of the hazard. Table 2 shows that many residents of Elegu Town Council had received flood risk warning from their relatives. Upstream community members having family relationships with the downstream community members alert their relatives about the likelihood of flood when the River Unyama flooded its banks. Because of the transboundary nature of the flood hazard, upstream community leaders became a better option of providing earlier flood risk warnings, which would enable the community affected by the flood to have adequate time to respond.

4.3.2 | Drivers of new relations between the community and local resources

New relations emerged between community and local resources because of the social market failure. There is no government for the flood early warning system. As Table 2 shows, the Government of Ugandaprovides food and non-food items as part of its post-flood response, but it does not support the flood early warning system. Because the community cannot afford to better technologies for flood monitoring, they rely on cheap and locally available resources.

4.3.3 | Drivers of new housing and bedding structures

Innovations in the housing and bedding structures occurred because of the uncertainty about flooding at night. The Elegu flood early warning system does not monitor and communicate flood warnings at night. This implies that the affected community faces a higher risk of losing lives and property at night than during the day. To mitigate this risk, community members constructed these housing and bedding structures. The structures are, therefore, a means of coping with the limitation of the Elegu flood early warning system.

5 | DISCUSSION

5.1 | Social innovations

The Elegu flood early warning system has been an innovation itself. This is because no such initiative has been in operation in Northern Uganda. Within the early warning system, a range of social innovations is embedded. Firstly, there are new inter-community relations. This finding is in line with Ahmed (2019) and Bhatt (2019b). According to Ahmed and Bhatt, new networks and partnerships emerged between upstream and downstream communities in India and Nepal following the establishment of the transboundary flood early warning system. Key among these networks has been the Trans-Boundary Citizen Forum (TBCF), which comprised local citizens from two communities living across the Nepal-India border, played an effective role in communicating the flood early warning information among the communities and alerted the at-risk communities ahead of time (Ahmed, 2019; Bhatt, 2019a).

Secondly, new relations emerged between communities and their local resources. Local resources were drawn upon for flood risk monitoring and response. This finding supports Khan et al. (2018) who argue that a community-based early warning system promotes the utilisation of local resources. The finding also supports the observation of Pradhan and Pandey (2019) that in the transboundary early warning system, upstream communities generate flood information using a simple low-cost instrument.

Thirdly, new housing and bedding structures, particularly raised flood and bedding emerged as a means to cope with flooding. These innovations are strategies for reducing flood exposure. The finding is similar to what Reynaud et al. (2013) reported in Vietnam, where flood elevation was adopted as a means of living with or adapting to floods.

5.2 | Drivers of social innovations

Social innovations in the Elegu flood early warning system were driven by several factors. Firstly, the new inter-community relations are driven by the transboundary nature of flood hazards. This finding concurs with Gupta (2019a, 2019b) and Bhatt (2019a). Gupta argues that "since disaster risks do not adhere to national boundaries, it is imperative to foster regional cooperation among nations that are exposed to common threats and hazards". Bhatt also asserts that the transboundary early warning system "works better in an environment of increased regional cooperation" and "whenever partnerships among a wide range of organisations across diverse sectors are struck". The Elegu flood early warning system, therefore, created inter-community relations because they are imperative for its operations.

Equally, the new inter-community relations were driven by kinship. The finding draws support from the work of Pradhan and Pandey (2019) on the flood early warning system across the India-Nepal Border where Family relations promoted cross–border upstream-downstream interactions along Ratu River in Sarpallo, Nepal, and Bhittamore, India. "We have family relations across the border in Nepal and we are excited to share knowledge and information which benefits both communities", an Indian woman revealed (Pradhan & Pandey, 2019).

Secondly, the new relations between communities and local resources are driven by social market failure, particularly the lack of government support for the flood early warning system. This finding is in line with the work of Gupta et al. (2021) in India and Nepal. Gupta observed that budgetary allocations in India and Nepal tend to prioritise response over preparation, despite the known cost savings associated with the latter and regardless of policy frameworks.

Thirdly, the innovation in housing and bedding structures was driven by the uncertainty or risk of flooding at night. The community members, therefore, created new housing and bedding as a means to adapt to and cope with the flood risk. This finding supports the idea of voluntary exposure to or living with the flood. Lassa et al. (2013) refers to voluntary exposure or living with the flood as an approach to dealing with a flood where communities decide to live in the same risky place but they manage to find some ways to adapt and cope with the risks by creating new housing structures or coming up with other new ideas, arrangement, designs or activities.

6 | CONCLUSION

The study assessed social innovations and drivers in a community-based transboundary flood early warning system. The study found that the flood early warning system generated threesocial innovations: new inter-community relations, new community-local resource relations, and new housing and bedding structures. New inter-community relations were driven by the transboundary nature of the flood and kinship. New community-local resource relations were driven by the lack of government support for the early warning system. New housing and bedding structures were driven by the uncertainty about the flood at night.

The study confirms the importance of social market failure in driving social innovations and the role of community-based flood early warning systems inpromoting the utilisation of local resources. The effectiveness of the transboundary early warning system in extending lead time and reducing losses was also confirmed. However, the early warning system was found to be effective only during day time, making residents of Elegu Town Council vulnerable to floods at night. The study, therefore, recommends government intervention in bridging this gap by installing telemetry because it can provide real-time flood risk information 24 h a day.

DATA AVAILABILITY STATEMENT

The data for this manuscript may be obtained from the corresponding author upon reasonable request.

ORCID

Vincent Canwat https://orcid.org/0000-0002-7538-2037

ENDNOTES

[1] Refer to Nicholls et al. (2015)

[2] Refer to Nicholls et al. (2015)

[3] Refer to Rüede and Lurtz (2012)

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