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Enhancing the sustainability of community-based flood early warning systems

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KEY ISSUES

Community-based flood early warning systems (CBFEWS) are effective at reducing flood risks for vulnerable communities, but are generally initiated, funded, and managed by external agencies. They need to be localised, preferably with the involvement of local government bodies, and made sustainable. The sustainability of a CBFEWS beyond the termination of funding assistance needs sustenance of at least four elements – financial, institutional, technological, and social. To increase sustainability, stakeholders must take ownership of the system and develop a standard operating procedure describing ways to (i) pay annually for CBFEWS operations (including mock drills, maintenance of evacuation routes, and maintenance of safe shelters) and technical maintenance (including repairs and spare parts), perhaps by setting up a revolving basket fund with contributions by municipalities, NGOs, and the private sector or by including such costs in the local administration's budget; (ii) institutionalise system management and operations with broad community participation, by setting up an institutional governing mechanism and strengthening community-based organisations and local groups;
(iii) procure the river gauging station and warning system where needed, transferring technology and knowledge as necessary; and (iv) increase the accuracy of flood warnings, and prepare communities to react effectively to warnings, while being aware of, and responsive to the needs of the most vulnerable populations.

Introduction

THE PROBLEM

Early warning systems (EWS) are one of the most effective ways to reduce the risk of loss of life and property from floods. By providing near real-time flood information around the clock, they reduce uncertainty and increase the lead time communities have before a flood hits, allowing for proper preparation and evacuation[1]. This additional time is particularly helpful for vulnerable sections such as women, children, the physically disabled, and poor and marginalised groups.

Though the Department of Hydrology and Meteorology (DHM) of the Government of Nepal has implemented EWSs at the national level along the country's major river systems – such as the Karnali, West Rapti, Babai, and Kankai[2] – it has not done so along its approximately 6,000 tributaries, which flood nearly every year[3]. Since 2015, a number of CBFEWS have been installed, with inexpensive technologies (costing approximately USD 3,500 at 2021 prices), have modest maintenance costs, and can be easily used, being low-tech. Through this technology, caretakers upstream receive flood information from a river gauging station and communicate warnings to partners, government agencies, and downstream communities in southern Nepal and northern India. One study estimated that an EWS in the Lower Karnali River Basin enabled households to save movable property, livestock, and vehicles worth NPR 117,027 (USD 1,083) each during a flood in August 2017[4]. The financial benefits, when compared to the cost of the EWS, were extremely high:

[1] Interview with Rinku Singh, downstream beneficiary of a CBFEWS on Ratu River, 2016, Mohattari. https://www.youtube.com/watch?v=IVoJy--9UgQ

[2] Bhandari, D., Uprety, M., Ghimire, G., Kumal, B., Pokharel, L., & Khadka, P. (2018). Nepal flood 2017: *Wake up call for effective preparedness and response*. Practical Action.

[3] Intergovernmental Panel on Climate Change. (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation (SREX)* https://archive.ipcc.ch/report/srex/

[4] Rai, R., van den Homberg, M. J. C., Ghimire, G., & McQuistan, C. (2020). Cost-benefit analysis of flood early warning system in the Karnali River Basin of Nepal. *International Journal of Disaster Risk Reduction*, 47. https://doi.org/10.1016/j.ijdrr.2020.101534

they ranged from between 24 times the cost of the EWS (assuming all households don't lose much cash during a flood and have a safe place to store grains) and 73 times (assuming households need at least two years to recover from flood damages), depending on the scenario[5].

Expanding the installation of CBFEWS would undoubtedly greatly benefit vulnerable communities. However, the system is not currently sustainable, seeing as it is largely managed and/or funded by external agencies (such as ICIMOD, Practical Action, Oxfam, Save the Children, and other like-minded organisations) and local partners. Externally-managed projects tend to be discontinued by communities once support for them ceases – not for lack of interest from the community but for lack of funds, expertise, and institutionalisation[6]. As such, communities must take ownership of these systems in a sustainable manner. Realising the potential of CBFEWS for saving lives, some local government bodies are trying to find the funds to operate CBFEWS, build local capacities to maintain them, and keep the system operational (such as with the CBFEWS in Ratu) to ensure they are sustainable at the local level. The DHM also monitors the information generated by different CBFEWS along with its own network of river gauging stations while issuing its flood alerts via mass SMS.

[5] Ibid

[6] Shrestha, M., Gurung, M., Khadgi, V., Wagle, N., Banarjee, S., Sherchan, U., Parjauli, B., & Mishra, A. (2021). The last mile: Flood risk communication for better preparedness in Nepal. *International Journal of Disaster Risk Reduction, 56*. https://doi.org/10.1016/j.ijdrr.2021.102118

Why the problem is important

Floods are devastating and frequent. Nepal is one of the most disaster-prone countries in the world, ranked 30th in terms of the vulnerability to the impacts of floods[7]. Nearly 150 people are killed by floods in the country annually[8]. Floods have affected lives and livelihoods, agricultural productivity, and hydropower production[9]. In 2017, a particularly devastating year, floods affected 1.7 million people and killed more than 160 in 35 districts. They inundated more than 80 per cent of the land in the Terai and caused USD 60.71 billion in damages – 3 per cent of that year's GDP. In 2020, according to the Ministry of Home Affairs, floods killed 42 people and affected 512 households.

Floods are increasingly unpredictable. In recent years, increasingly erratic and unpredictable rainfall patterns and increased climatic variability have led to more severe and frequent flood disasters in the Hindu Kush Himalaya (HKH) region[10]. Deforestation, population growth, and the encroachment of floodplains are also contributory factors[11].

Vulnerable groups are particularly at risk. Women, children, the elderly, the physically disabled, and marginalised groups tend to be especially affected during flash floods. A longer lead time is helpful for them as they often require more time than others to prepare and evacuate to safe ground. Their vulnerability may stem from a lack of mobility (either due to physical constraints or because of cultural norms)[12], access to information[13], resources, or decision-making power. Typically, more women than men die during landslides and floods[14].

CBFEWS are increasingly effective, affordable, and user-friendly. Past EWSs in Nepal often had very short lead times (for example, the viewing tower system in Chitwan) or had limited accuracy (for instance, the one with manual gauge systems in Kailali). Hi-tech EWSs can be expensive, using technology such as artificial neural networks or satellite data to create complex flood models[15]. In contrast, CBFEWS provide real-time data, are relatively less costly, are comparatively low-tech, user-friendly, and relatively simple to maintain and troubleshoot.

Nepal's national policies encourage locally owned and operated EWSs. In February 2011, the Nepal Risk Reduction Consortium recommended the installation of early warning systems at each level of government to create resilient communities. The 2017 Disaster Risk Reduction and Management Act, 2074 recommended that local governments develop and operate early warning systems at the community level[16]. However, this policy has largely not been implemented. Most local governments do not have their own EWSs, and direct most of their budgets towards post-disaster response.

National flood warnings are not sufficient at the tributary level. Though the government provides national, basin, and sub-basin flood forecasts and warnings, there are no hydro-meteorological stations along tributaries of rivers, and early warnings are not location-specific. Moreover, the flow of information to communities tends to be fractured[17]. Flood information is relayed from the DHM to the National Emergency Operation Centre and then to branching levels of administrative subcommittees at the provincial, district, local, and community levels. The coordination between these committees is insufficient[18], and those at the local and community levels are often underfunded and lack annual plans, leading to gaps in communication. Communities either do not always receive information, or the information they receive is overly technical, or tends to be in Nepali and English, languages that many of the most vulnerable do not comprehend[19].

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[7] United Nations Development Programme. (2020) Annual report 2020, Nepal. https://nepal.un.org/sites/default/files/2021-06/UNDP-NP-Annual-Report-2020.pdf

[8] Mandal, K. C. (2020, July 17). *Despite tackling disasters every monsoon, Nepal fails to learn from experience*. The Kathmandu Post. https://kathmandupost.com/national/2020/07/17/despite-tackling-disasters-every-monsoon-nepal-fails-to-learn-from-experience

[9] Wester, P., Mishra, A., Mukherji, A., & Shrestha, A. B. (Eds.). (2019). *The Hindu Kush Himalaya assessment: Mountains, climate change, sustainability and people*. Springer Nature Switzerland AG. https://lib.icimod.org/record/34383

[10] Ibid.

[11] Rajbhandari, R., Shrestha, A. B., Nepal, S., Wahid, S., & Ren, G.-Y. (2017). Extreme climate projections over the transboundary Koshi River Basin using a high resolution regional climate model. *Advances in Climate Change Research, 8(3)*, 199–211. https://doi.org/10.1016/j.accre.2017.08.006

[12] Foran, T., Lahiri-Dutt, K., Sugden, F., Neupane, N., Goodrich, C., & Wahid, S. (2015). *Multiple inequalities: Women and livelihoods in the Koshi river basin*. ICIMOD. https://lib.icimod.org/record/32537

[13] Neumayer, E., & Plümper, T. (2007). The gendered nature of natural disasters: The Impact of catastrophic events on the gender gap in life expectancy, 1981–2002. *Annals of the Association of American Geographers, 97(3)*, 551–566. https://doi.org/10.1111/j.1467-8306.2007.00563.x

[14] Shrestha M., Gurung, M., Khadgi, V., Wagle, N., Banarjee, S., Sherchan, U., Parjauli, B., & Mishra, A. (2021). The last mile: Flood risk communication for better preparedness in Nepal. *International Journal of Disaster Risk Reduction, 56*. https://doi.org/10.1016/j.ijdrr.2021.102118

[15] Rajbhandari, R., Shrestha, A. B., Nepal, S., Wahid, S., & Ren, G.-Y. (2017). Extreme climate projections over the transboundary Koshi River Basin using a high resolution regional climate model. *Advances in Climate Change Research, 8(3)*, 199–211. https://doi.org/10.1016/j.accre.2017.08.006

[16] Ministry of Home Affairs. (2017). *Disaster Risk Reduction and Management Act, 2074*. Government of Nepal.

[17] Shrestha, M., Gurung, M., Khadgi, V., Wagle, N., Banarjee, S., Sherchan, U., Parjauli, B., & Mishra, A. (2021). The last mile: Flood risk communication for better preparedness in Nepal. *International Journal of Disaster Risk Reduction*, 56. https://doi.org/10.1016/j.ijdrr.2021.102118

[18] Ibid.

[19] Ibid.

Objectives and sources

The Constitution of Nepal 2015 made local governments responsible for implementing disaster risk reduction activities. This was followed by the 2017 Disaster Management Act recommendation that local governments develop and operate early warning systems at the community level. Unfortunately, early warning systems are not fully integrated into the legislations and operational structures of local governance mechanisms. This is true for disaster departments and disaster risk reduction and management committees at the municipal, ward, and community levels[20]. In light of these considerations, this paper aims to draw attention to the factors that undermine the sustainability of CBFEWS and propose measures that local policy makers could take in response to enhance their sustainability.

It draws on, and provides evidence from three wide-ranging sources: (i) a field survey conducted with stakeholders and end users across three river basins – the Ratu, Khando, and Gagan, (ii) secondary literature, and (iii) about a decade's worth of ICIMOD's experiences in implementing CBFEWS and working with communities on the ground.

Main findings

CBFEWS reduce the vulnerability of communities to flash floods

The CBFEWS is an integrated system that allows communities to take necessary precautions in the period immediately preceding a flood in order to save lives and movable assets such as important documents, livestock, and grain. It also guides communities on taking appropriate steps during and after a flood. The system consists of a gauging station on the river to monitor water levels, a transmitter unit installed at the riverbank, and a receiver unit in a caretaker's house, which communicate wirelessly. When the water reaches 'alert' levels, the caretaker is notified through a loud siren from the receiver unit, after which he/she first verifies the situation and then conveys the received information to a range of stakeholders, who disseminate it to community members. Local government officials and security agencies also use the warning to carry out their own operations and take precautionary measures[21].

CBFEWS enable a longer lead time (from 30 minutes to 8 hours, depending on the distance between the station and the downstream community) and greater accuracy than traditional 'watch and warn' systems, which required observing the rivers physically. A CBFEWS is especially effective when such informal arrangements are fallible, such as at night[22]. It allays the consuming psychological distress experienced by those in flood-prone areas, especially at the possibility of overnight flooding[23].

Longer lead times particularly enable vulnerable populations to move to safer places, and to protect their assets and properties. Women have also praised the system for allowing them to evacuate 'with dignity', given cultural norms[24]. Poorer or disadvantaged communities, who in some locations are likely to live by the river in single-storeyed houses – and in whose houses the water level will be relatively higher and cause more damage – are able to invest more time in preparation[25].

CBFEWS costs must be met annually to ensure the system's long-term sustainability

CBFEWS costs are relatively low. But most municipal budgets in Nepal retain development funds for costly embankment construction, and for post-disaster relief. So interested municipalities must find a way to raise the one-time funds for the instrument: roughly USD 3,500 or about NPR 415,000 as of June 2021. One-time installation and fieldwork costs – consisting of testing and installation, setting up the server and web portal for data visualisation, etc. – are approximately NPR 260,000.

Externally funded systems tend to be abandoned once funding ceases[26]. For the CBFEWS to operate sustainably after installation, municipalities must find a way to meet the annual maintenance costs. (Specific suggestions as to how these can be met have been made in the recommendations below.) These funds will ensure that personnel associated with the CBFEWS are adequately compensated for their work and remain motivated; that community members remain sensitised

[20] Karn, D. S. (2022, October 14). An overview of early warning system (EWS) in nepal- how inclusive and resilient to communities at risk. SpotlightNepal. https://www.spotlightnepal.com/2022/10/14/overview-early-warning-system-ews-nepal-how-inclusive-and-resilient-communities-risk/

[21] Interview with Satish Kumar Singh, former chairperson of Tilathi Koiladi Rural Municipality, 2021, Saptari.

[22] Interviews with Deepak Jha and Ratan Nayak, executive director of Sabal Nepal, Saptari and beneficiary of a CBFEWS on Gagan River, Siraha, 2021

[23] Rai, R., van den Homberg, M. J. C., Ghimire, G., & McQuistan, C. (2020). Cost-benefit analysis of flood early warning system in the Karnali River Basin of Nepal. *International Journal of Disaster Risk Reduction*, 47. https://doi.org/10.1016/j.ijdrr.2020.101534

[24] Online interview with Sanjay Pandey, executive director of Yuganter, 2021.

[25] Ibid.

[26] Christie, F. & Hanlon, J. (2000). *Mozambique and the great flood of 2000*. Oxford: James Currey; Shrestha, M., Gurung, M., Khadgi, V., Wagle, N., Banarjee, S., Sherchan, U., Parjauli, B., & Mishra, A. (2021). The last mile: Flood risk communication for better preparedness in Nepal. *International Journal of Disaster Risk Reduction, 56*. https://doi.org/10.1016/j.ijdrr.2021.102118

and know how to make best use of the warnings; and that the system itself continues to be technically sound, with third-party check-ups and regular repairs of spare parts, when needed. In Nepal, all this will cost NPR 135,000. The approximate breakdown of these costs as of June 2021 is given in Table 1.

TABLE 1 **ANNUAL MAINTENANCE COSTS OF A CBFEWS IN 2021**

Item	Cost (NPR)
Caretaker remuneration	15,000 (3,750 x 4 months)
Caretaker communication charges	5,000
Data transmission from equipment	5,000
Annual maintenance contract	70,000
Community workshops	20,000
Spare parts	20,000
Total	135,000

Local participation increases the effectiveness of CBFEWS

CBFEWS have a bottom-up, people-centred approach. The community owns the system and participates actively in each stage of operation, which confers three main benefits:

- The system is more likely to be trusted. Community members, through local groups and social networks, are in direct contact with focal persons[27] and community-based organisations (CBOs), who are aware of differentiated needs and offer detailed, two-way communication with the local government. As a result, the community is more responsive to alerts[28, 29].
- The system is more likely to be effective. Communities use local knowledge, resources, and capacities to tailor a system to its particular circumstances and the needs and priorities of women and men across different social groups. For instance, warnings are disseminated through SMS, WhatsApp, or phone calls, depending on popular usage. Unlike the forecasts and warnings issued by the DHM through SMS which are generic to a major river basin, CBFEWS warnings are based on real-time data and have the specific scope of covering only one tributary. They are hence more accurate and effective.
- The system is more likely to be sustained. Local authorities responsible for CBFEWS management are motivated to make it a priority, being directly accountable to constituents who reap the benefits of a reliable and well-functioning system.

For these benefits to accrue, there must be (i) robust links between the local government and the people, and (ii) efficient regulation and management of the CBFEWS by local government.

The system's efficacy depends on the accuracy of early warnings

The CBFEWS must be able to predict floods with a reasonably high accuracy. Accurate warnings generate trust in the system, so communities do not hesitate to act. Conversely, a low accuracy of warnings diminishes trust and perceived usefulness over time. Accurate warnings also allow policy makers and security personnel to coordinate post-disaster relief efforts.

The accuracy of CBFEWS alerts has been hampered on occasion by

- inaccurate readings and false alerts, due to river diversions or changes in the riverbed profile from natural silt deposition or construction activity. Although such inaccuracies are largely avoided by manual verification[30], this is not a foolproof measure.
- no warning being generated at all, in a situation where a settlement is prone to floods from multiple rivers but the CBFEWS monitors water levels along only one.

Community preparation is essential for warnings to be effective

After an alert is received, vulnerable communities must respond both properly and efficiently. Thus, community members must be sensitised, trained, and equipped with resources (for example, with ropes and boats) in advance.

Preparatory measures do not always consider the needs of the most vulnerable. For example, with seasonal labour migration from the Terai into India, many households lack young men, leaving flood preparation to the women and the elderly. Many women find it difficult to both protect their houses against flooding, evacuate, and manage their children[31]. In India, it was found that many women are often confused about effective responses.

[27] Interview with Ratan Nayak. Beneficiary of a CBFEWS on Gagan River, Siraha, 2021

[28] Rajbhandari, R., Shrestha, A. B., Nepal, S., Wahid, S., & Ren, G.-Y. (2017). Extreme climate projections over the transboundary Koshi River Basin using a high resolution regional climate model. *Advances In Climate Change Research*, 8(3), 199–211. https://doi.org/10.1016/j.accre.2017.08.006

[29] Interview with Rajesh Jha, DRR officer of Tilathi Koiladi Rural Municipality, 2021, Saptari.

[30] Interview with Deepak Jha, executive director of Sabal Nepal, 2021, Saptari.

[31] Focus group discussions by ICIMOD in Manohara and Sisuwa, March 2019.

Recommendations

The sustainability of a CBFEWS beyond the termination of funding assistance needs sustenance of at least four elements – financial, institutional, technological, and social. It calls for ownership of the system by key stakeholders such as nodal agencies, local government bodies, disaster response units, civil society, and local communities. Every CBFEWS should develop a standard operating procedure based on these four elements.

Financial aspects

PLAN FOR AND COMMIT TO A SUSTAINABLE FUNDING MODEL

Stakeholders must generate funds to meet CBFEWS costs in the face of a limited municipal budget, ideally in a self-sustaining way. A revolving fund, which generates interest annually to meet all or a portion of those costs, may be an attractive solution. A basket fund, which pools capital from multiple flood-affected municipalities and sources, may be particularly effective (see Box 1).

Recommendations: Municipalities sharing a flood-prone tributary should officially commit to a common basket fund through a memorandum of understanding or letter of cooperation. They should coordinate to each contribute a principal amount towards a basket fund, if necessary sharing the amount according to the proportion of vulnerable residents in each administrative area. It is important afterwards to adopt policies and best practices to regulate the fund so that it is spent judiciously and not on incidental costs[32].

NGOs and the private sector – especially financial institutions, which have mandatory CSR requirements – have a role to play in setting up a fund, for instance, by contributing an initial amount or offering an account with a favourable interest rate. District and provincial officials –for example, chairpersons of wards, and mayors – can help forge agreements. In some areas, municipalities have declared interest but have not yet made formal commitments[33].

However, the basket fund put together may only cover a portion of the expenses. To meet the shortfall, municipalities could, for instance, use the basket fund to generate funds towards operational costs and create a cost-sharing mechanism to pay caretaker salaries[34]. Or they could secure a small financial pledge from vulnerable populations. For instance, one study showed that 98 per cent of the residents of the Lower Karnali River Basin were willing to pay NPR 79 a year for five years, just under NPR 700,000 in total[35].

BOX 1: **CREATING BASKET FUNDS CAN SUSTAIN A CBFEWS**

In 2019, the chairperson of the Tilathi Koiladi Rural Municipality in Saptari District, Satish Singh, took steps to establish a CBFEWS basket fund. He brought together three municipalities – Tilathi Koiladi, Rajbiraj, and Rupani – along the Khando River, an NGO (Sabal Nepal), a private sector partner (a local cooperative), and a district-level governing body.

Singh combined public funding with the cooperative's corporate social responsibility (CSR) funding to amass a capital amount of NPR 1.3 million. He negotiated a 14 per cent annual interest rate with the cooperative, 2 per cent above its standard rate. The interest amount generated by the fund covers operational and maintenance costs of the CBFEWS and caretaker compensation, and also augments the principal annually.

Institutional aspects

STRENGTHEN FLOOD-RELATED COMMUNITY-BASED ORGANISATIONS AND LOCAL GROUPS

The community, through community-based organisations (CBOs) and local groups such as mothers' groups, women's self-help groups, youth groups, local clubs, community disaster management committees, and social networks, can be integrated into all levels of CBFEWS operations. These groups act as the interface between community members and the local government and other actors, such as NGOs and relief organisations. Such two-way links ensure that policy makers are apprised of community needs, and that those needs are being met satisfactorily. As such, these groups can be used for monitoring and warning operations[36], and for gathering data on needs and vulnerabilities. A 2017 study in the Ratu watershed revealed that 6.1 per cent of households received flood information from CBOs, on par with TV and FM radio[37].

[32] Interview with Rajesh Jha, DRR officer of Tilathi Koiladi Rural Municipality, 2021, Saptari.

[33] Interview with Satish Singh, chairperson, Tilathi Koiladi Rural Municipality, and Deepak Jha, executive director of Sabal Nepal, 2021, Saptari.

[34] Interview with Rajesh Jha, DRR officer of Tilathi Koiladi Rural Municipality, 2021, Saptari.

[35] Rai, R., van den Homberg, M. J. C., Ghimire, G., & McQuistan, C. (2020). Cost-benefit analysis of flood early warning system in the Karnali River Basin of Nepal. International *Journal of Disaster Risk Reduction*, 47. https://doi.org/10.1016/j.ijdrr.2020.101534

[36] Shrestha, M., Kafle, S., Gurung, M., Nibanupudi, H., Khadgi, V., & Rajkarnikar, G. (2014). *Flood early warning systems in Nepal: A gendered perspective*. Working Paper 2014/4. ICIMOD. https://lib.icimod.org/record/29959

[37] Rajbhandari, R., Shrestha, A. B., Nepal, S., Wahid, S., & Ren, G.-Y. (2017). Extreme climate projections over the transboundary Koshi River Basin using a high resolution regional climate model. *Advances In Climate Change Research, 8(3)*, 199–211. https://doi.org/10.1016/j.accre.2017.08.006

The participation of CBOs and local groups is especially helpful in building awareness and preparedness[38], given their proximity to the local population. These groups are effective at community mobilisation, and can organise sensitisation campaigns that are in sync with people's needs and capacities. For instance, they may help create highly relevant communication materials (posters, charts, announcements, and flyers) to spread awareness. CBOs and local groups could also be used to prepare for post-disaster responses, such as in training search-and-rescue teams.

However, although numerous, these groups tend to be weak, lack proper training and authority, and tend to form or work in an ad-hoc manner. As such they are ineffective for long-term CBFEWS operations if they remain detached from a broader institutional framework.

Recommendations: A bridging mechanism between the local government, CBOs, and informal local groups could be developed. Furthermore, there is a need to (i) build capacities of early warning-related CBOs and local groups, and (ii) strengthen their links to local government.

NGOs could be mobilised to strengthen CBOs and local groups by building awareness and providing them the proper guidance, training, and resources to serve their communities. They can also liaise between CBOs/ local groups and local government bodies and lay out a strategy to encourage cooperation. With strengthened links to local government, CBOs and local groups can better assess needs and relay community concerns.

DEVELOP LOCAL INSTITUTIONAL MECHANISMS

Stakeholders should regularly convene to review CBFEWS performance and sustainability. For instance, they should see that it is properly maintained and adapts to changing circumstances (such as diversions in the river, or changes in flooding patterns due to construction work). But without a robust institutional mechanism in place, there is the risk of haphazard or irregular management, which erodes sustainability.

Recommendations: Develop a participatory institutional mechanism at the local level. Establish a steering committee comprising major stakeholders of representative bodies (municipalities, NGOs, CBOs, etc.) for democratic management.

- Ensure the committee represents women (50 per cent participation) and marginalised groups. Introduce binding policies to make meetings mandatory for elected officials[39].
- Ensure the committee meets at least twice a year, before the flood season to ensure adequate preparation, and afterwards, to review lessons learnt and to revise the approach (social, technical) for the subsequent year.

This committee should

- develop an annual CBFEWS calendar for activities to be conducted before, during, and after the monsoon, such as technical maintenance and revision of flood warning levels (if needed) and communication charts to optimise warning dissemination,
- monitor the changing vulnerabilities and needs and priorities of women and other vulnerable groups by gathering differentiated data, and undertake mock drills,
- review caretaker performance and make changes as necessary, and
- meet on an ad hoc basis to review one-off technical matters such as changes in the river that alter the efficacy of the CBFEWS

Technical aspects

EXPAND THE RISK MESSAGING SYSTEM TO PROVIDE WARNINGS TO MORE COMMUNITIES

CBFEWS have limited coverage in the Ratu, Khando, and Gagan rivers. Widening implementing the systems would minimise losses in more communities. Technology transfer to a local manufacturer (see Box 2) and outscaling confers varied benefits.

BOX 2: **PASSING ON EXPERTISE AND RESEARCH**

In Nepal, ICIMOD's partner, Sustainable Eco Engineering (SEE), manufactured and maintained CBFEWS equipment. During the implementation of the CBFEWS in Pakistan, ICIMOD worked with SEE to transfer the technology to a local company, Buraq Integrated Solutions (BIS)[40]. Crucial here was the transfer of expertise and research, so that BIS could not only manufacture the instrument independently but also maintain and improve it as necessary.

[38] Burningham, K., Fielding, J., & Thrush, D. (2008). 'It'll never happen to me': Understanding public awareness of local flood risk. *Disasters, 32(2)*, 216–238. https://doi.org/10.1111/j.1467-7717.2007.01036.x

[39] Interview with Satish Singh, chairperson of Tilathi Koiladi Rural Municipality, 2021, Saptari.

[40] ICIMOD. (2019). *Proceedings of the meeting on outscaling community based flood early warning systems (CBFEWS) in Pakistan*. Workshop Proceedings 2019/3. ICIMOD.

Recommendations: A cost-benefit analysis (comparing the economic and human losses borne by communities every year – and hence avoided if a CBFEWS were to be installed – against the initial and recurring system costs) could be conducted to determine if a CBFEWS is beneficial for their community, and secure the system for their communities if it is.

Policy makers at the local and provincial levels could facilitate technology and knowledge transfers to a local manufacturer. This would help outscaling, reduce equipment, servicing, and transportation costs and issues, and greatly ease the process of acquiring spare parts and conducting repairs.

EXPLORE WAYS TO IMPROVE THE PRECISION OF WARNINGS

Improving the precision of warnings makes the system more reliable and trustworthy. It would also ease pressure from the manual checks that caretakers and others must conduct.

Recommendations: Explore technical improvements to the system. For example:

- Install sensors in multiple locations to minimise the chance of inaccurate readings (because of river diversions, for instance)[41]. Use cost-benefit analyses to see if this is viable.
- Improve back-up measures. For example, install alarms in all villages[42], install higher capacity back-up power, and upgrade the solar panels so that the system remains operational through extended periods of cloudy weather[43].
- Explore ways to communicate warnings in the event of power and network outages[44].

The possibility of installing a second system at sites where multiple rivers may flood, could be explored conducting a cost-benefit analysis towards this.

Social aspects

IMPROVE PREPAREDNESS OF VULNERABLE COMMUNITIES

A CBFEWS only saves lives and property if communities are adequately prepared and equipped to respond to warnings. However, programmes to sensitise people on how to respond to floods tend to be infrequent; shelters are uncommon and tend to be insufficiently large[45]; and there are few or no clear evacuation procedures in place.

Any efforts to improve preparation must be centred on the needs of the most vulnerable. Because community needs are heterogenous, those of the most vulnerable must be investigated and met. For instance, in Bihar, the discovery that women were unlikely to respond properly to floods spurred the creation of a special awareness programme for their benefit, in partnership with the Women's Welfare Forum[46].

Recommendations: Stakeholders should better sensitise the local people about flood anticipatory actions and responses, for example, by conducting mock drills periodically, preferably before the monsoon every year, to train for preparation and rescue, or by disseminating awareness material. Such measures should keep in mind possible constraining factors among the vulnerable, such as the lack of literacy and differentiated levels of risk of flooding. NGOs working on women's issues can also be linked to the process to achieve gender integration in early warning systems[47].

We would suggest the following measures:

- Ensure that risk information is clear and tailored, disseminated in local languages, and through various modes (sirens, FM radio, etc.) that are also accessible to the illiterate. Ensure that target populations understand the information.
- Regularly gather gender-disaggregated data to explore the particular needs and hurdles faced by vulnerable populations in preparing for floods. Be aware of changing vulnerabilities.

[41] Interview with Rajesh Jha, DRR officer of Tilathi Koiladi Rural Municipality, 2021, Saptari.

[42] Interview with Bijaya Gupta, chairperson of Red Cross, Mohattari, 2021, Mohattari.

[43] Online interview with Sanjay Pandey, executive director of Yuganter, 2021.

[44] Shrestha, M., Gurung, M., Khadgi, V., Wagle, N., Banarjee, S., Sherchan, U., Parjauli, B., & Mishra, A. (2021). The last mile: Flood risk communication for better preparedness in Nepal. *International Journal of Disaster Risk Reduction, 56*. https://doi.org/10.1016/j.ijdrr.2021.102118

[45] Interviews with Ratan Nayak, beneficiary of a CBFEWS on Gagan River, Siraha and Damodar Mukhiya, beneficiary of a CBFEWS on Khando River, Saptari, 2021.

[46] Online interview with Sanjay Pandey, executive director of Yuganter, 2021.

[47] Shrestha, M., Goodrich, C., Udas, P., Rai, D., Gurung, M., & Khadgi, V. (2016). Flood early warning systems in Bhutan: A gendered perspective. Working Paper 2016/13. ICIMOD. https://doi.org/10.53055/ICIMOD.632

- Ensure that drills and awareness programmes are well-attended by vulnerable populations, prioritising their schedules and convenience.
- Ensure post-disaster responses are alert to the needs of the vulnerable. For example, safe areas should be accessible to the elderly and safe for single women and adolescent girls. Provide drinking water and toilets, and counselling to address post-traumatic stress disorder.

EXPLORE WAYS TO IMPROVE INFORMAL LINKAGES BETWEEN UPSTREAM AND DOWNSTREAM COMMUNITIES

In the event of system failure, informal personal links between members of upstream and downstream communities ensures warnings are communicated. Because of physical distances between settlements, such back-up measures must be actively cultivated. Such links can bear fruit in varied ways: in Assam, India, cooperation over CBFEWS brought about marriages between households of upstream and downstream communities. In another context, informal linkages have channelled flood warnings from Nepal across the border to downstream communities in India (in Supaul, Sitamarhi, etc.) and saved lives there even as local governments are trying to formalise the communication of such warnings.

Recommendations: Explore ways to improve linkages between upstream and downstream communities, tailored to the communities in question. Potential ways include the hiring of social mobilisers to strengthen links, or the facilitation of economic interactions between communities[48].

[48] Interview with Deepak Jha, executive director of Sabal Nepal, 2021, Saptari.

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