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A Preference-based Analysis of Community Level Flood Early Warning Techniques in the West Rapti River Basin, Nepal

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Abstract

This paper analyses the value of flood warning information and most reliable media for disseminating early warning in rural communities of Nepal with a case of the West Rapti River Basin. Five focus group discussions and 240 household interviews were conducted to assess the preferred early warning techniques and communication medium. A siren/alarm system was ranked the most preferred technique. The sound produced from this system can easily be heard by a large mass of people at varying locations within a short time. Flood early warning information from the right place, on the right time, to the right people provides in advance the notice of flood occurrence which helps to reduce casualties and damages.

Keywords: Early warning system; Floods; Siren/alarm; West Rapti River

Introduction

A flood early warning system (EWS) is an integrated system of techniques and plans, which provides detection of and coordinated response to flood emergencies. These systems are complex in various existing geophysical regions. Due to population pressure and economic opportunities available during non-flood period, people tend to migrate and settle in the floodplains of big rivers [1,2]. In most of the places community-based EWS are developed and implemented. Community-based EWS is a people-centred approach that empowers individuals and communities threatened by natural hazards to act in sufficient time and in an appropriate manner in an attempt to reduce the possibility of casualties, damage to property and loss of livelihood [3,4]. Coordinated linkage between the downstream and upstream communities is extremely essential for effective operation of an EWS for flood risk impact minimization. Heavy rainfall upstream will have a direct impact on downstream communities. Downstream communities will only be able to get timely warning when this can be provided from upstream communities who act as the observers.

Developing and operating an efficient EWS should focus on effective communication and dissemination techniques based on the level of flood risk. Furthermore, allocation of the roles and responsibilities of each stakeholder considering the special need of all community members for preparing operation and management plan is necessary [5]. Making use of the other techniques like telephone and communication with the local police station can help disseminate information to the people faster. Communication details with gauge observers and other stakeholders should be collected, compiled and distributed. Large and scattered communities might need more than one siren to ensure that all households can hear the alarm [6]. Wireless radios of security personnel can be used to relay the information where normal telephone network is out of order or not available. Security personal should be trained to communicate for the early warning purpose [7].

The EWS management committee should introduce and assign operators with different colored flags/lights corresponding to the severity of the situation to warn people with hearing impairment. Similarly, handheld microphones and speakers also might have to be used. An effective communication system between the upstream and downstream community members should be developed such that it is founded the principle of “Live and let them live” [8]. Literature is relatively scarce on how the different approaches are dealing with uncertainty in the case of climate change (CC) adaptation and flood warning system; i.e. how adaptation can cope with uncertainty in floods. Water-induced disasters are being more frequent and intense due to impacts of CC in recent times [9]. Devkota et al. show that the effects of CC on future precipitation are likely at the annual and basin scales and yet more at the seasonal and sub-basin scales which directly affect the river flows [10]. There is always the inherent danger of severe damage and disruption to the daily lives and economic activities of the inhabitants during the events of flooding.

CC is likely to contribute to increase in flood magnitude and damage to public and private property in the Terai plains of Nepal, for example in the West Rapti River Basin [11,12]. Flood inundation in the Terai is mainly associated with the unplanned construction of road embankments, diversion head works as well as encroachment of flood plains. Since ancient times, settlements in plain areas of WRRB have been in close proximity to the West Rapti River (WRR) mainly due to easy accessibility to water for domestic use and irrigation [13]. The banks of the WRR consist of fertile alluvial land and farming is the main occupation of the inhabitants. However, frequent flooding in recent years has damaged the productive agriculture land through standing water, river banking cutting, and sediment deposition in paddy lands, leading to heavy loss of crop production. The

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consequences of the construction of Laxamanpur barrage and Kalkalawa afflux bound by the Government of India in the Indian territory adjacent to Nepal-India border has resulted in significant increase in recurring flood problems with inundation spreading out over hundreds of hectares of low elevated fertile land as it completely blocks the natural flow of WRR and its tributaries [7].

In this context, it has been felt that a properly designed and implemented EWS can save lives and reduced damage to property by increasing the time to prepare and respond to the threat of flood prior to its occurrence. Therefore, this study analyses the preferred techniques of flood EWSat the community level in the WRRB and makes and attempt to prioritize the most effective among the selected ones.

Study Area

The study was carried out in five Village Development Committees (VDCs), namely, Holiya, Kamdi, Lalmatiya, Sohanpur and Gangapur in the WRRB, covering Banke and Dang districts of Nepal (Figure 1). Although not snow-fed, the WRR is a major perennial river of Nepal with it origin in the middle mountains. The WRR flows southward up to Dang and thereafter, bends westward in Banke. The main tributaries are Madi River and Jhimruk River. Other smaller tributaries include Arung, Khairi, Maguwa, Jhijhari and Dunduwa rivers. The average annual rainfall of the basin varies from 1151 mm to 2489 mm [14]. More than 80% of the rainfall occurs during the four months of monsoon (June through September). The primary occupation of more than 80% of the residents of this basin is agriculture. Flash floods in the WRRB are often the result of cloudbursts upstream.

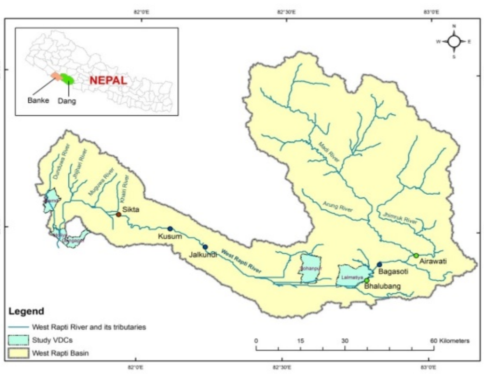

Figure 1: Location of the study area.

Methodology

As the first step, a total of five focus group discussions (FGD) were held in the study VDCs lying in the flood prone areas. People who have first-hand experience in flood warning system, such as farmers, foresters, VDC secretaries, school teachers and members of local non-governmental organizations (NGOs), were invited to participate in the FGDs. In total, 71 people participated in the FGDs. In the discussion, local people were asked to prepare a list of most common flood warning techniques that have been used in the study area over the past 20 years. Then, they were further requested to identify five application techniques that are most relevant for household (HH) survey. A simple random sampling with proportion of HH numbers was considered and a total of 240 households (over 25% of the total population) were randomly interviewed. During the field visit, the key person of the household was requested to rank selected flood warning techniques against a 1-5 scale, where 1 is the least and 5 the most preferred option. Finally, the options were ranked using weighted average index (WAI) with calculation as shown in Equation 1. For detailed discussion on the use of this index, the readers are referred to Maraseni & Zinquan and Maraseni [15,16].

$$\text{Weighted Average Index (WAI)} = \frac{F_1W_1 + F_2W_2 + F_3W_3 + F_4W_4 + F_5W_5}{F_1 + F_2 + F_3 + F_4 + F_5}$$

$$WAI = \frac{\sum FiWi}{\sum Fi} \quad (1)$$

Where,

F=frequency of the response;

W=weight of each response scale;

i=index to each response range (from 1 to 5)

Results and Discussion

Flood risk level and migration

Table 1 presents a classification of respondents based on their responses to flooding. Responses show that each household in the study area was affected by floods in one way or the other. The residents have been categorized into three based on their responses: those who temporarily migrate during flood periods; those who live in the area at risk; and those who have permanently migrated. Of the 240 household survey respondents, 39.2 % reported being temporarily displaced from their house due to flooding, 48.3% reported living in their houses at areas with high flood risk and the remaining 12.5% reported that they had permanently migrated from their original houses.

Classification of respondents	Number	%
Temporarily migrated	94	39.2
Lived in the area at risk	116	48.3
Permanently migrated	30	12.5
Total	240	100
Source: Household survey		

Table 1: Types of respondents on the basis of their responses to flooding (N=240).

Out of the total 94 respondents who temporarily migrated due to the flooding, 33% migrated for two or three days and 32% migrated for four to seven days. Similarly, 12% and 7% of the respondents migrated for 8 to 14days and more than 15days, respectively. About 16% of the respondents shifted from their homes to a safer place for a day (Figure 2).

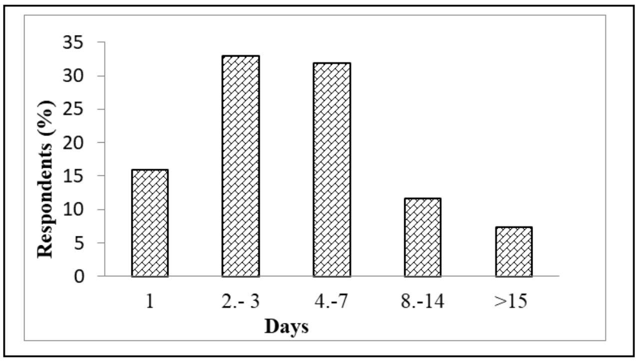

Figure 2: Maximum number of days of temporary migration in the study area (N-94).

About 31% of the respondents migrated to a public place (school, Red Cross building, temple, etc.), 27% migrated to relatives' houses, 24% to neighbours' houses and the remaining 18% to other nearby places such as road side areas, forests and open space (Table 2) to take shelter.

Place of shelter	No. of the respondents	%
Relatives' house	25	27
Public place	29	31
Neighbours' house	23	25
Other nearby place (roadside, forest area etc.)	17	17
Total	94	100
Source: Household survey		

Table 2: Migrated respondents and their displacement after the flood event (N=94).

Perceived flood frequency and magnitude

People's perception on the frequency of floods were analysed based on the HH survey results. About 80% of the respondents faced flood problems every year. Similarly, about 20% of the respondents mentioned that flooding recurred once every five years. Local people were also asked about the average duration of water logging in their area during the flood season. The results are presented in Figure 3a. The response on water logging duration varied from less than a day to more than four days. About 44% of the respondents reported that they faced a water logging problem for one to two days following flooding and another 39% faced the same problem for three to four days. The reason for this was mainly because of excessive flood water and lack of proper drainage system in the study VDCs.

Respondents were also asked about the maximum depth of water during floods. Out of the 240 respondents, about 25.7% mentioned water depths less than 0.3 m, 39.5% mentioned depths between 0.3 and 1 m, and 34.7% mentioned depths greater than 1 m (Figure 3b).

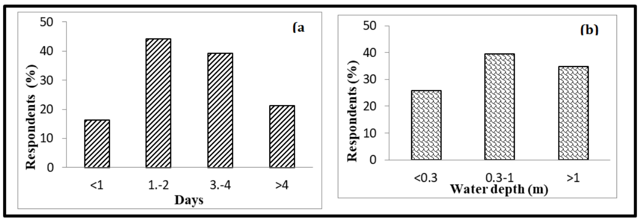

Figure 3: (a) Duration of water logging after rain and floods and (b) maximum water depth during flooding perceived by respondents (N=240).

Effectiveness of tools and techniques for early warning

In the past, people used indigenous knowledge and traditional practices for flash flood warning such as assigning flood watching volunteers from village and door to door communication. The communities also decided to use hand operated sirens to distinguish the warning massages from their cultural instruments which are used for other community events. Understanding of traditional practices in the area helps recognize what is needed and accepted locally. Although traditional practices are not based on scientific facts, they are formulated on the basis of past observation and have been proven to be effective enough for people to adapt even in harsh conditions.

An effective EWS can reduce flood risks and save lives and property. Such a system should provide a clear message to those people who are at risk and stimulate them to take actions. The community managed EWS operating in the study area was found to be very popular for flood management. Five types of tools and techniques used as part of the EWS were identified in the study area, namely, (1) Hand operated sirens; (2) Telephones/Mobile/SMS; (3) Wireless radios; (4) FM radio and television stations and (5) Coloured flags/light. People's perception on the effectiveness of these tools is presented in Table 3. "Hand operated sirens" was found to be the most effective means for flash flood warning (WAI=4.6), followed by "Telephones/Mobile/SMS (WAI=4.3). Communicating the waring through "Wireless radio" ranked third (WAI=3.6); "FM radio and television stations" ranked fourth (WAI=3.2), while the use of "Coloured flags/light" method, which is relatively laborious, time consuming and hard to implement, was regarded as at least effective of these (Table 3).

The most preferred early warning method in this study area was siren/alarm because: i) the sound produced by sirens/alarms can easily be heard and identified; ii) there is no need for expensive instruments nor a skilled human resource to operate it; iii) it is equally effective whether one is at home or in the fields; and iv) warning can be delivered to a large mass of people within a short period of time.

Telephones/Mobile/SMS was ranked as the second most effective method for delivering warning about floods. Nowadays, almost everyone has a mobile phone with them at all times, mobile phones are cheap and handy and also within the reach of the poor. Mobile phones enable easy communication between people through direct conversations or text messaging. Information can be conveniently shared through mobiles system; however, the reliability is still inadequate. "Wireless radios" was the third most popular choice as it is also another way of quickly transmitting message; however, it is effective only for small areas. Disseminating information through colour flags/light was considered difficult due to limitations in power supply; as a result, it is the least preferred method for flood warning.

Responses	Most effective	Highly Effective	Moderately effective	Less effective	Least effective	Weighted average index WAI	Rank
Hand operated sirens	164	56	16	3	1	4.6	I
Telephones/Mobile/SMS	134	65	31	8	2	4.3	II
Wireless radios	27	100	95	16	2	3.6	III
FM radio & television stations	22	72	86	45	15	3.2	IV
Colored flags/light	17	39	58	101	25	2.7	V

Table 3: Tools and techniques used for communication and dissemination of flood early warning information (N=240).

During the FGDs, the participants were also asked to list the modes of communication of flood warning they believed would be most reliable in the future. They eliminated two commonly used methods, “door to door communication” and “shouting”, and added three more methods, namely, “newspaper”, “radio/FM” and “television”. These five methods were then presented in the household survey in order to assess people’s preferences. As in the case of other early warning systems, “siren/alarm” and mobile/SMS” were ranked high as effective means of communication (Figure 4). The discussion made above regarding alarm/siren and mobile/SMS as effective tools is equally applicable here. It has to be noted here that the local people have limited transportation facilities and poor access to newspapers and other forms of mass communication. More than half the people are illiterate; and they often cannot afford to buy TV or radios and expensive power backups which mean that, even for those who do own such equipment, these are not reliable information sources. As a result, these were less preferred options for issuing early warnings.

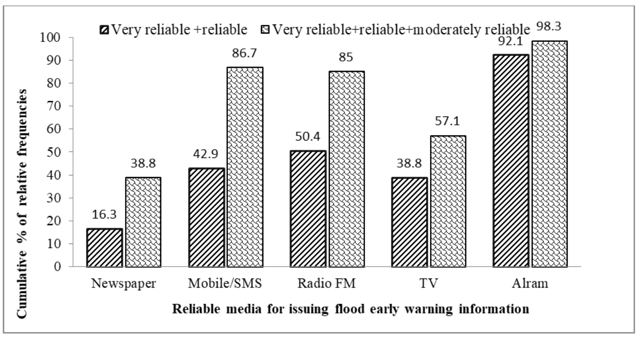

Figure 4: Reliability of media for issuing flood early warning information.

Flash floods are common in a country such as Nepal where high volumes of water flow through a steep terrain in a short duration due to intensive rainfall. Floods also often carry large rocks and huge amounts of sediment and other debris. Previous studies by Fakhruddin et al.; Gautam shows that an effective flood EWS also requires improvements in weather warning with the need to determine the appropriate lead time for warnings and to improve the accuracy of warnings and forecasts, particularly in monsoon season [7,17,18]. Sirens/alarms installed at the rivers are found to be most effective systems for providing flash flood warning in the WRRB. Social development officers advise that setting up the EWS in these areas not only helps minimize the loss of lives and property downstream but is also an effective approach for people living in the poverty and ignorance [19].

Clear flood early warning information is necessary to save lives and property but sometimes those are not sufficient. Coupling knowledge with practice creates a good platform for flood risk management. The local residents of the study area used various tools and techniques for the communication and dissemination of flood early warning information. Although preferred tools and techniques are applicable for short term flood response, integrated socio-economic and future CC scenarios with long term land use change must be considered for long term flood risk management [20].

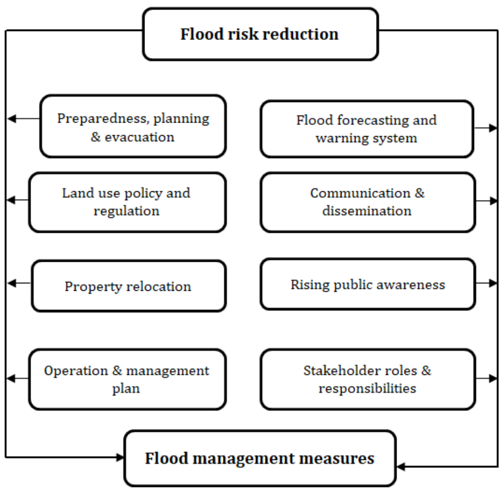

Figure 5: Flood risk management measures.

A flood risk management framework which includes structural as well as non-structural changes (Figure 5) is effective if it can be implemented at the community level. Hence, this could be integrating socio-economic and future CC scenarios with long term land use change for flood risk reduction [21]. Generating awareness and preparedness about floods, its impacts and evacuation is one of the key necessities. Similarly, devising and implementing operation and management plans is required for successful flood management. Moreover, special focus needs to be given to developing robust flood forecasting and EWSs which are capable of timely disseminating the early warning. On the whole, stakeholders and the community itself needs to be given the responsibilities for effective flood risk management. Of course, external help can always be sought when local resources are not sufficient [22]. Moreover, advances in flood forecasting and monitoring must go parallel with accurate and comprehensive vulnerability and risk information.

Conclusion

The banks of the WRR consist of fertile land and agriculture is the main occupation of the area. Flash floods in the WRRB as in are often the result of cloudbursts in the upstream areas of its catchment. However, since the past two decades, flood vulnerability has increased as a result of the construction of Laxmanpur barrage and Kalkalawa afflux bund by the Government of India in the Indian territory that completely blocks the natural flow of the river and its tributaries. The upstream communities can inform the downstream communities about the possibility of floods based on the rainfall characteristics and thus the flood related risks can be significantly minimized. This study analysed the locally preferred tools and techniques of flood EWS, whose implementation help save lives and protect land and other physical infrastructures. Although these tools and techniques are applicable for short term flood response, integrated socio-economic and future CC scenarios with long term land use change must be considered for long term flood risk management.

Getting the right information out to the right people at the right time and right place is very important for flood risk reduction. Moreover, advances in flood forecasting and monitoring must go in parallel with accurate and comprehensive vulnerability and risk information. In the future, flood vulnerability, risk scenarios assessment and vulnerability mapping should be standardized through appropriate methodologies. Further collaboration with weather satellites from the region is also required for better rainfall forecast and potential flood risk management.

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