early warning

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ORIGINAL PAPER

Evaluation of Golestan Province's Early Warning System for flash floods, Iran, 2006–7

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Abstract Golestan province located in NE Iran is well known for deadly flash floods. This study aimed to evaluate the region's Early Warning System (EWS) for flash floods. We used an adapted version of the questionnaire developed by the United Nations International Strategy for Disaster Reduction. We reviewed documents on the EWS of Golestan, and conducted a qualitative study comprising interviews with experts and affected people in Kalaleh and Minoodasht. Results were discussed by an expert panel. Regarding risk knowledge, there was a hazard map at Provincial Disaster Taskforce (PDT) drawn by the provincial Office for Water Resource Management, but no risk analysis was available. Local people were aware of their exposure to flooding, but not aware of the existence of a hazard map and their vulnerability situation. In terms of monitoring and warning, PDT faced serious limitations in issuing Early Warnings, including (1) an inability to make point predictions of rainfall, and (2) the absence of a warning threshold. Dissemination and communication issued by the Meteorological Office followed a top-to-bottom direction. The contents were neither clearly understood by other institutions nor reached the potential recipients within an appropriate time frame. There was a need for a comprehensive response plan with adequate exercises, and no evaluation framework existed. Golestan EWS is in dire need of improvement. To fill in the gaps ensuring local people receive timely warning, we propose a community-based model called "Village Disaster Taskforce" (VDT) in which individual villages act as operational units, but interlinked with other villages and PDT.

Keywords Flash flood · Early warning system · Iran

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Introduction

Floods belong to the category of water-related disasters and represent the most common type of natural hazards, occurring in both developed and developing countries. They account for over one-third of the total disaster-related losses and two-thirds of the world's disaster-affected population (ISDR 2005). The developing nations, however, lose a greater percentage of their gross domestic product (GDP) because of disasters damage (ISDR 2004). Local statistics are indicative of a growing frequency of flood occurrence in Iran: the number of floods rose from 215 in the 1960s to 405, 812, and 2,053 over the subsequent three decades (Moosivand and Mirzaie 2006).

The greatest flood risk to human life comes from flash floods, defined as a flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 h, with minimal or no warning (NOAA 2005). The province of Golestan is located in the north-east of Iran and stretches between the latitudes of 36°30′ and 38°8′N and the longitudes of 53°57′ and 56°22′E. Golestan is bounded by the provinces of Semnan on the south and North Khorasan on the east, and by the Caspian Sea and Mazandaran province on the west, and the Republic of Turkmenistan on the north (MPO 2004). Golestan is well known for the history of deadly flash floods in 2001, 2002 and 2005, causing 468 deaths (Fig. 1).

The province of Golestan has a surface area of over 20,000 km^2 (1.3% of the total area of Iran) and a population of 1.4 million; hence the population density in this province is around 81 individuals per square kilometer. There are 11 cities in Golestan— including the provincial capital Gorgan— and the ratio of rural to urban population is 1.17. The province is part of the Northern Temperate Zone and is endowed with remarkable climatic diversity: the southern section has a typical mountain climate, the central and south-western regions have a temperate Mediterranean climate, and the southern part is semiarid or completely arid. The absolute minimum daily temperature is −1.4° C and the maximum 46.5° C. Annual rainfall in Golestan ranges from 250 to 700 mm, and the province harbors four main water basins— namely Atrak, Gorganrood, Ghare-Sou, and Gorgan Bay (MPO 2004).

Floods represent a constant obstacle to the local development programs. From 1990 to 2005, the province has witnessed 64 floods, causing an estimated total loss of US$112 million in various sectors. During the half-decade of 2000–2005, Golestan experienced 3 years of the most deadly flash floods in its recorded history. The flash flood of 11 August 2001 happened in the eastern part of the province, about 8 km from Minoodasht and 107 km from the province capital, within the Gorganrood basin. The worst flooding came from the river Doogh (Madarsoo), and the number of human victims reached 330—including 252 deaths and 72 missing individuals (GUMS 2001). The flash flood of 13 August 2002 occurred in the Minoodasht area in the same basin of the 2001 flood and led to 42 deaths and 30 missing (GUMS 2002). The 2005 floods occurred on 30 July and 9 August, again in the eastern region but this time near the city of Kalaleh. The first happened in the Golidagh Heights, killing 22 people; the second was in the Golestan Forest and cost 26 lives. In total, 18 individuals went missing in the two floods of 2005 (GUMS 2005).

According to meteo-hydrological analysis (MOJA and JICA 2006), on the day of the 2001 flood, 80–180 mm rainfall occurred on about 50% of the basin area, aggregated to 150–180 mm in the Golestan Forest Park. On the day prior to the flood, the maximum rainfall was 50 mm. Except for Kalaleh, maximum relative humidity (RH) was higher on the day of the flood than on previous days, with maximum RH of 94% in Soodaghlene. Maximum air temperature had dropped gradually from 2 days before and reached the lowest values at all stations in the basin on the day of the flood, i.e. 21.25°C (average for four stations). In the 2002 flood, on the day of flood occurrence 40–108 mm rainfall occurred on about 35% of the basin area in the central part of the basin with peak rainfall at Dasht Shad. On the day prior to the flood (12 August) there was 24 mm rainfall at Tangrah but no rainfall at other stations in the basin. Values of maximum RH were higher on the day of flood than on previous days at Nardin and Kalaleh stations, but the values were lower at Soodaghlene and Dasht Kalpoush stations. The maxi-

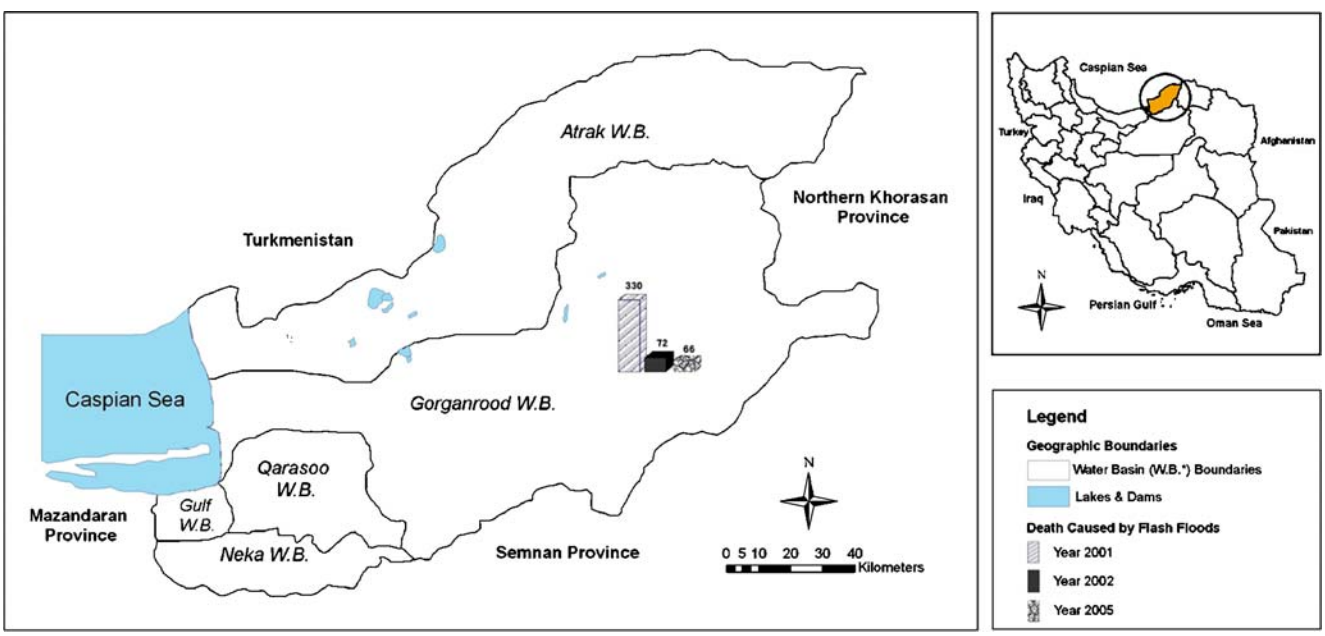

Fig. 1 Golestan province's water basin and flash flood mortality, 2001–2005

mum RH was up to 94% in Soodaghlene. Values of maximum air temperature at stations in the basin have shown exactly the same trend as in the 2001 flood with an average of 22.9°C. In the 2005 flood, 80–137 mm of rainfall occurred on about 55% of the area and daily rainfall aggregated to 100–130 mm centering on the Golestan Forest. There was no rainfall at any stations in the basin on the day before the flood. According to the Tangrah station, maximum recorded hourly rainfall was 80 mm/h, showing high intensity rainfall which caused a violent flash flood. Rainfall distribution pattern revealed that about 76% of total rainfall occurred within the first 4 h of rain. The air temperature showed a decreasing trend from 2 days before the flood occurrence to 19.7°C. Relative humidity (RH) started to increase gradually up to 99.7%.

The establishment of an early warning system (EWS) is one of the non-structural measures designed to mitigate the effects of floods. According to the United Nations International Strategy for Disaster Reduction (ISDR 2006a), it includes provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response. As defined here, the EWS comprises much more than simply predicting the occurrence of a disaster.

According to the experience of the 2000–2005 flash floods, the stakeholders including the local community and health system were really concerned about the effectiveness of the EWS in Golestan province. This research was conducted to evaluate the elements of an effective EWS in the province, including risk knowledge, warning issue, communication and dissemination of the warning, response plan, and evaluation. The findings were supposed to show the points for improving the system's performance.

Materials and methods

Data collection for this study was based on the questionnaire developed by ISDR in the Third International Conference on Early Warning, Germany 2006 (ISDR 2006b). The questionnaire comprised the domains of Risk Knowledge, Monitoring and Warning Service, Dissemination/Communication, and Response Capability. We translated the questionnaire into Farsi and added a further domain, i.e. Evaluation, to those mentioned above.

The assessment of the Golestan's flash flood EWS included the following three steps:

1. A review of the literature on the previous experience of similar events in Iran and other countries, including a search of the internet with the following keywords "Flash flood" and "Early warning".
2. Collecting and reviewing documents on the EW process from the following organizations: Golestan Disaster Taskforce, the local Meteorological Office, the local Office for Jihad-e-Agriculture, the local Water Authority, the local Ministry of Health, and Ministry of Interior.
3. A qualitative study comprising individual in-depth interviews with experts in the above-mentioned organizations (eight interviews in all), in-depth interviews with four senior residents of villages with a history of flash floods in the Kalaleh and Minoodasht regions. Then, we used expert panel methodology to develop an appropriate model of EWS for Golestan province. The panel included eight individuals, including provincial managers involved in the EWS and experts in related disciplines, e.g., information management, water engineering, meteorology, and public health. At the beginning of the session, the panelists were fed the results of individual interviews. We started the first round by brainstorming to generate ideas on how the current ESW works and how it can be improved to respond to immediate threats of flash floods in the local community. The opinions were grouped together under the main elements of the EWS, defined in the "Materials and methods" section of this paper. Accordingly, a chart was drawn to summarize the model. The second and third rounds were continued by asking the participants' agreement on each element. Each round was followed by a group discussion giving the opportunity to elaborate the reasons for the level of agreement. We ceased this iteration process in the fourth round by obtaining agreement of at least three-quarters of the participants on all elements.

Results

Risk knowledge

As specified in the country's Comprehensive Rescue and Relief Plan, the responsibility for disaster preparedness and risk management at the provincial level rests with the Disaster Taskforce of the province Governorate. Based on their scope of responsibility, various organizations in Golestan have taken measures to gauge the current hazard and vulnerability levels in the province. At the time of the study, the local Water Authority was in the process of drawing hazard maps and performing vulnerability studies with the help of a consulting firm. The only hazard map of practical value available at the Provincial Disaster Taskforce was the one drawn by the provincial Office for Water Resource Management. Senior residents of villages believed that inhabitants were aware of their exposure to the risk of flooding, but not informed about the hazard map, its components, or its applications. The only exception was the village of Tarjanli, where the locals had received copies of a hazard map during a drill organized by the Japanese International Cooperation Agency (JICA) in 2005. There was no database giving access to data on hazard and vulnerability or findings of previous studies. The appropriate place for such a database would have been the Provincial Disaster Taskforce.

Overall, it was very difficult to draw a comprehensive picture of the existing hazard and vulnerability levels. Despite the efforts of various local organizations; this problem was aggravated by the lack of a unified hazard database.

Monitoring and warning

Flood hazard monitoring and warning in Golestan relies on the observations made by the province's Meteorological Office (MO). The office does not have an independent weather forecast unit and obtains the relevant data from the State Meteorological Organization (SMO). The process of flood prediction was composed of the following stages:

1. Studying synoptic data from Golestan, neighboring provinces, Middle East and European countries.
2. Using the Internet to analyze actual and prognostic maps from the SMO and prominent international meteorological organizations.
3. Making quantitative forecasts for northern Iran (including Golestan and the marine forecast frontier of Gilan)
4. Announcing the weather forecast for the province and warning the public of impending floods or other adverse climatic events. The SMO has established more than seven climatic and rain gauge stations along the Madarsoo River, and these stations span the three provinces of Semnan, Golestan, and North Khorasan. Communication with Tangrah and Dasht stations (within the basin of Madarsoo) and with Farsian and Farang stations (within the basin of Ughan) takes place through ordinary telephone lines. Golestan is equipped with two automatic rain gauges (located in the National Park and the Plain of Golestan) plus 115 man-operated rain gauges, 28 of which are located in the eastern part of the province. The gauges are equipped with electronic warning devices for the winter, and they measure the amount of rainfall to a precision of 0.1 mm, with a maximum measurement amplitude of 7 mm/min. The accuracy of 5-day forecasts for the province was said to be around 85%, but documented data were not available for making a formal assessment. Under the present circumstances, it is not possible to make site-specific predictions, as this would require the addition of 12 automatic devices and 20 rain-gauge stations. Such an infrastructure will take some time to establish, but it will enable local meteorological organizations to make "point" forecasts (in addition to regional forecasts). Because of the lack of accurate data, the Golestan MO has adopted a rainfall of 20 mm/h as an empirical warning threshold. This means that in the event of rainfall in excess of 20 mm, the meteorological office will notify the Provincial Disaster Taskforce of heavy precipitation. During the first flooding episode in Kalaleh in 2005, a rainfall of 30 mm was adopted as the threshold for evacuating the region. Relief workers were advised to leave the area when precipitation reached a level of 60 mm/h.

After the floods of 2001 and 2002, the Ministry of Energy established an on-line flood prediction system in Golestan, but we did not observe a link between data from this system and the start point of the EW process in the province.

To sum up, the Provincial Disaster Taskforce faces serious limitations in issuing early flash flood warnings, including (1) an inability to make point predictions of the rainfall, and (2) the impossibility of estimating the probability of flood occurrence at the specified level of precipitation in each region due to the absence of a definite warning threshold. Such risk estimates would have to be based on extensive studies of the relationship between the amount of the rainfall and the rise in water levels in any particular region (flooding risk).

Dissemination and communication

The Meteorological Office uses two types of written documents for EW of flash floods: communiqués and warnings. In emergency situations, the Office issues "Urgent Alarms", communicated by phone or in person. In the event of an impending disaster, the Office notifies the Governor's Office and the Provincial Disaster Taskforce in writing, with copies being sent to other organizations. The warning notes are signed by the Office's Director General and Flood Prediction Officer, and sent by fax and mail. Mobile phones are employed for urgent communication after office hours. According to the Office, the timing of communication/correspondence before a heavy rainfall is as follows:

- 6 days before a heavy rain fall: verbal communication
- 3–5 days before a heavy rainfall: written communiqué
- 1–3 days before a heavy rainfall: written warning
- 1–8 hours before a heavy rainfall: urgent alarm

Local organizations communicate with residents through television and radio broadcasts. The Provincial Disaster Taskforce does not receive warnings from other organizations. Here are samples of the warnings issued by the Golestan MO:

Communiqué

Forecasting maps indicate the presence of a relatively active high-pressure system over Eastern Europe and the Black Sea. The system is moving eastward and is likely to cause precipitation and low temperature over the northern half of the country. The forecast for Golestan Province includes increasing cloudiness and dropping temperatures, thunder showers and snowfall in higher altitudes. Some inundation of streets and public places can be expected.

Warning

A low-temperature, high-pressure system is entering the northern part of the country and is likely to cause the following weather changes in Golestan: increased cloudiness, rain and snowfall in mountainous regions, winds and falling temperatures. This pattern will continue until Friday. We expect frost in the mountains, rising water levels in rivers and slippery road conditions.

Limitations in message contents

- Incomplete understanding of the technical terms e.g. low- and high-pressure systems, by other organizations
- Failure to distinguish communiqués from warnings because of similarity of contents
- Absence of clear demarcations between different regions in the province
- Operational inefficiency of the messages in the context of flash floods with regard to lead-time and location
- Failure to ensure adequate communication with the public because of poor comprehension of technical terms—especially in rural areas
- Failure of the target organizations (e.g., health system, environmental and agricultural institutions) to act on the warnings in a timely fashion

Overall, communication through these messages follows a top-to-bottom direction. The contents are not clearly understood by communities and institutions, and they do not reach the potential recipients within the appropriate time frame. Although the Golestan MO can predict some episodes of heavy rainfall, its failure to determine the probability and precise location of eventual flash floods has made communities and institutions rather indifferent towards warning messages. The time it takes for a warning message to reach its final target (i.e., the flood-prone communities) is inappropriately long compared to the lead-time for flash floods (15–60 min in the case of Golestan). Therefore, the overall efficiency of the Province's dissemination and communication system must be regarded as very low.

Response capability

There were no documented flash flood response plans or guidelines in the PDT or within the province's health system. The absence of reliable hazard maps and the inability to determine the location of eventual flash floods have made it impossible to define the exact scope of any response operations. There were no well-defined plans or drills for responding to flash floods and the local residents' reaction to such events is entirely based on experience.

Evaluation

There were no written guidelines or procedures for evaluation and monitoring of the various components of the EWS or its cost-effectiveness and overall effectiveness—either for the current warning system or for those used during previous flooding episodes. Likewise, there were no comprehensive reports of the past events within the province's health system. The existing reports were confined to a general description of the event, without any evaluative components or comparisons with pre-determined standards. Hence the flood EWS in Golestan is in need of a framework that would make it possible to evaluate the system's overall effectiveness, the function of the various components, and economic analyses.

Discussion and conclusion

Predicting flash floods and preventing potentially disastrous consequences is the joint concern of the EWS and the health system, and a proactive approach in this regard would require close cooperation between experts in the domains of public health, meteorology, and hydrology (Ebi and Schmier 2005). Our study showed that various components of the flood EWS in Golestan are in dire need of improvement. The forecasting component lacks precision and is unable to make point predictions. Messages from the Golestan MO take too long to reach other organizations and the public. Forecasting of flash floods is limited to predicting rainfall, with no warning of the probability of water level rises or their intensity. This is mainly due to a lack of adequate hydrologic, topographic, and terrain data, and calls for extensive engineering studies and the creation of operational risk maps. The situation is further aggravated by ineffective communication among various organizations and agencies involved in flood warning.

To mount an effective response, local communities must receive precise and specific flood warnings. However, warning messages in their current form are poorly comprehensible for recipients, and there are no accurate hazard maps or well-defined response thresholds for vulnerable regions. Experience from previous floods has shown that the lead-time for a flash flood can be as short as 15 min (depending on terrain conditions and topography). Accurate estimation of risk (including hazard, vulnerability, and readiness assessments) requires extensive geographic, social, and other technical studies which are often time-consuming and costly studies of the region. The most comprehensive study so far is the joint project undertaken by the Japanese International Cooperation Agency (JICA) and the Iranian Ministry of Jehad-e-Agriculture (MOJA and JICA 2006). Preliminary assessments show that, even under the best circumstances, the project will not be complete before 2016, with flash floods posing a constant threat over this long period.

It is now widely recognized that correct implementation of an early warning system coupled with community participation can be very effective in reducing damage to human life and property (Ebi and Schmier 2005; Malilay 1997). Recent experience from Golestan underlines the importance of community participation in reducing the death toll from flash floods (a good case in point is the 2005 flood in the village of Qulaq-Kassan). It must be noted, however, that the success of local initiatives is dependent upon the existence of a political climate that understands and supports community participation. Hence, there have been calls for integration of all local planning centers into larger organizations operating at province or country level (ADPC 2006).

Taking into account the current limitations in the EWS and the fundamental principles laid out above, we propose a model for the creation of a "Village Disaster Taskforce" (VDT), in which individual villages act as operational units. The model would overcome the limitations of the current EWS and response to the immediate threat of flash floods

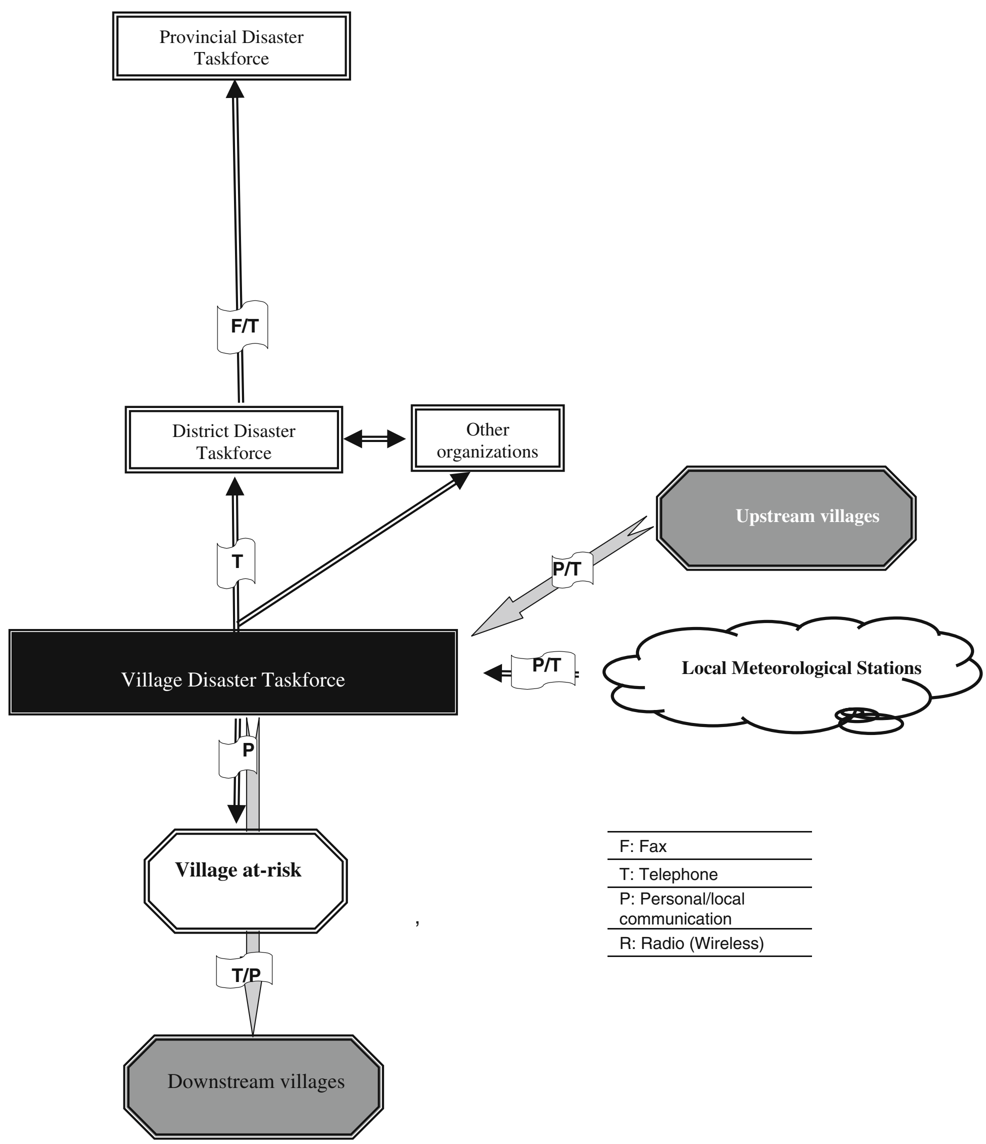

Fig. 2 Suggested model for an early flash flood warning system, with the Village Disaster Taskforce acting as the starting point of the warning process

to local communities by facilitating the warning dissemination and communication to the grassroots. It would not replace a high-tech early warning system, but would strengthen the system at the local level. The model is very much in line with the Comprehensive Rescue and Relief Plan, ratified by the Council of Ministers in April 2003. The Plan has paved the way for the creation of Disaster Taskforces on country, province, and district levels, but there are no provisions for the establishment of such structures in villages. The characteristics of a VDT, focused on a down-top approach, and facilitation of warning dissemination and communication to the grassroots, can be summed up as follows (Fig. 2):

- Early flood warning must be start at peripheral (village) level, not at the province capital
- The VDT will receive warning data of a possible heavy rainfall from meteorological centers and upstream villages and transmit the warning to both local and downstream communities. Observations of the current rainfall and experience from previous episodes can be useful in predicting an eventual flood.
- The VDT will decide on the most effective means for communication, often in cooperation with the local community. For example, Taskforces in different villages can liaise by telephone and notify the District Disaster Taskforce in the event of an impending flood risk. Simultaneous with this and even before notifying District authorities, the VDT members can use telephones, sirens, motor vehicle horns, mosque loudspeakers, or even shouting in public places to warn the local residents.
- Communication with downstream villages exposed to the risk of flood can take place through phone calls to their Early Warning centers. When phone lines are cut or non-existent, the only means of communication would be the dispatch of motor vehicles.
- In cooperation with the VDT and the local community, a hazard map could be drawn up for each village with the aim of increasing risk knowledge and promoting an appropriate response.
- A VDT may include the following members: village governor (as the representative of the Government), the village council (representing the community), the village primary health care worker (representing the health system and familiar with the local community's health and demographic status), and representatives from the Mobilized Resistance Forces (Basij) and the Red Crescent. This composition is recommended because of the need for members who enjoy the locals' trust and respect and who are well-organized, accountable to the community, and easy to educate. These people are well placed to establish good rapport with both local communities and government authorities. The inclusion of representatives from agencies with potentially overlapping scopes is prompted by the need for promoting effective communication. Flash floods may supervene at any time (midnight or on holidays) and the existence of more than one source of information can guarantee a high degree of sensitivity for the whole warning system.
- Suggested evaluation indices are: the number of people who have received the early warning message, the number who have shown appropriate response to the message, the sensitivity and specificity of the warning, and the number of deaths and injuries (as an index of ultimate effectiveness).

The model may have some limitations in its prediction and dissemination components. Raising technical capabilities to allow accurate predictions and promoting various means of communication (alarm sirens) can ameliorate the current shortcomings. Formation of VDTs and their initial success can pave the way for delegation of more tasks and responsibilities to these local institutions; indeed, many of the functions specified in the Comprehensive Relief and rescue plans can eventually devolve on the VDT.

Decentralized, community-based management of disaster situations was underlined as a global strategy in the Hyogo Declaration. The strategy has been successfully used for different types of hazard and in both developed (Germany, USA, Norway) and developing (Bangladesh, Cambodia, Eastern Timor, Central America) countries. Among the models proposed and tested so far, the Community Disaster Management Committee in Cambodia and the Village Disaster Management Committee are two models that bear the greatest structural similarity to the VDT model outlined in this article (ADPC 2006).

Conclusion

The EWS in Golestan needs functional improvements in the domains of risk knowledge, monitoring/warning, dissemination/communication, and response capacity. The formation of VDTs (within the framework of the Comprehensive Relief and Rescue Plan) will create an ideal setting for making use of the local capabilities and promoting community participation in disaster management. Along with improving the monitoring and warning technology in Golestan province, we recommend strengthening of community-based approaches.

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