Rainfall-Based Sediment Disaster Warning Systems in Taiwan

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1. INTRODUCTION

Establishing warning systems and evacuating inhabitants are recognized as an important approach for disaster risk reduction, and the nationwide rainfall-based sediment disaster warning system was established in 2002 in Taiwan[1]. Because Taiwan's *Disaster Prevention and Response Act* only stipulates debris flows disaster but not slope failures and landslides, Taiwan's existing sediment disaster warning system was designed only for debris flow disasters. Here, we introduce Taiwan's sediment disaster warning system, and discuss the problems we face.

2. WARNING MODEL

At the beginning, Taiwan's warning system also used short-term and long-term rainfall indexes to define the CL for each township, and the alert would be issued if the snake line exceeded the CL. To meet the demand of alerts in village-scale and an easy-to-understand index for inhabitants' self-evacuation during typhoons or heavy rainfall, Taiwan developed a new rainfall-based warning model known as Rainfall Triggering Index (*RTI*). Its method of calculation is summarized as Eq.(1a) and Eq.(1b).

$$RTI = I \times R_t \tag{1a}$$

$$R_t = \sum_{i=0}^{7} \alpha^i R_i \tag{1b}$$

where I is 60 minutes of rainfall intensity; R_t is the effective accumulated rainfall which is the amount of rainfall for the antecedent i days (R_i); α is a weighting factor and is set to be 0.8.

To determinate the representative value of *RTI* for each township, each historical rainfall event in the township could be drawn as a point in the graph, and RTI_{10} (i.e., the debris flow occurrence probability is 10%) and RTI_{90} could be demarcated by a manual method (see **Figure 1**)[2]. To set a rainfall threshold for easier public understanding and local application, a critical accumulated rainfall (R_c) is calculated by taking the rainfall intensity at 10 mm/h, i.e., using the value of RTI_{70} divided by 10 and would be modified into the closest 50mm interval. According to list from Soil and Water Conservation Bureau (SWCB) in 2014, the critical accumulated rainfall ranged from 250 to 600 mm.

3. ALERT ISSUING SYSTEM

The sediment disaster alerts in Taiwan is issued by the central government (SWCB) using mass media, telephone, FAX, the Internet and volunteers, and the issuing timing adopts a fixed schedule (e.g. daily 5:00, 11:00, 17:00, 20:00 and 23:00). The alert is divided into two levels, yellow alert and red alert. The yellow alert means the sum of the next 24hrs forecast rainfall and the effective accumulated rainfall (R_t) is greater than R_c, and the local government and inhabitants should prepare for

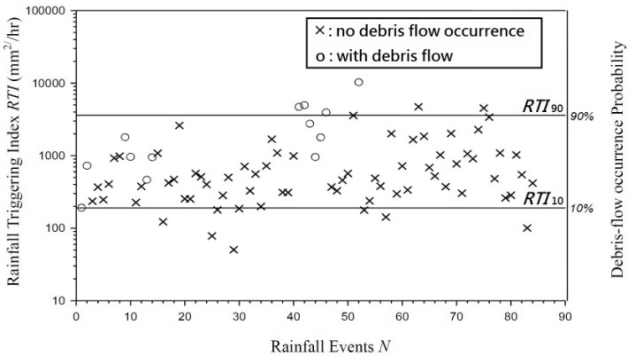

Fig. 1 Classification of debris-flow occurrence probability based on rainfall triggering index[2]

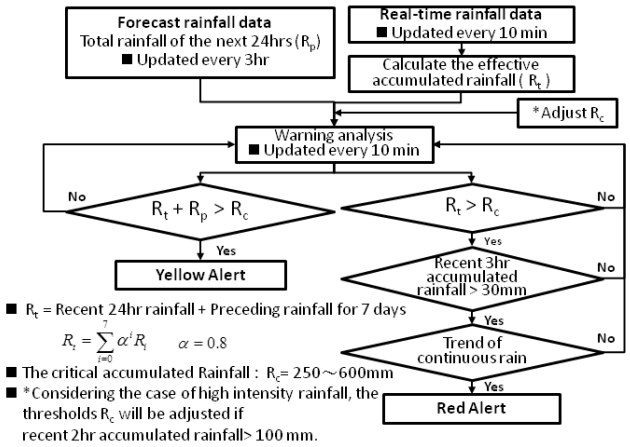

Fig. 2 The process of issuing debris flow disaster alert in Taiwan

Debris-flow Disaster Early-Warning Information Report

Time Date/Month/Year No. OO

Subject: Issuing debris flow disaster Red/Yellow Alert, and the warning areas are showed as the Tables.

Suggestions: OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO

County	Township	Critical Accumulated Rainfall (mm)	Warning Areas		
			The number of potential debris flow torrents	Warning Level	Villages (The number of potential debris flow torrents)
Pingtung	Shizi	500	17	Yellow	Danlo(4), Nanshi(3), Neishi(2), Shizi(2), Zukon(3), Neiwen(2) Chaopu(1)
	Wutai	400	2	Red	Wutai(1)、Ali(1)
	Sandimen	400	1	Red	Dalai(1)
		400	6	Yellow	Chinye(1), Chinsan(1), Anpo(1), Koasoa(3)
OOO	XXX	550	12	Yellow	…
	XXX	450	5	Red	…
	XXX	600	1	Yellow	…
		350	7	Yellow	…

Fig. 3 The format of debris flow disaster alert from SWCB

evacuation; the red alert will be issued when the R_t is greater than R_c, and the local government could execute the mandatory evacuation of the inhabitants in the warning areas. The process for issuing debris flow disaster alert is shown as in **Figure 2**, and the format of debris flow disaster alert is shown as in **Figure 3**. In addition, the detailed warning information is also presented using Google Maps and Google Earth on SWCB's website.

4. DISCUSSIONS

Existing rainfall-based sediment disaster warning systems in Taiwan indeed provide quite benefits for disaster prevention. However, a good warning system not only needs to promptly issue alerts before a disaster occurs, but must also avoid false alerts since local governments and inhabitants will ignore the warnings if there are too many false alerts. Because the existing rainfall-based warning systems only use rainfall as warning indexes, the performance is not good in warning hit rate, false alert rate, and warning cover rate (see **Figure 4**). That is, it remained a number of deficiencies in the warning system. These are as follows.

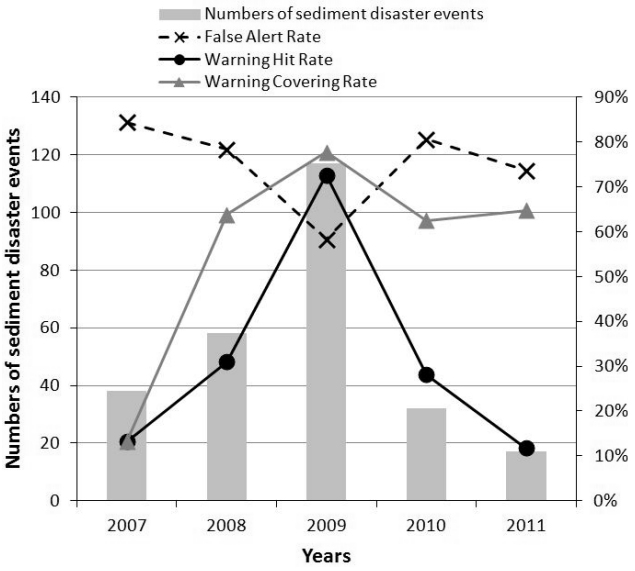

Fig. 4 The numbers of sediment disaster events and warning effectiveness in Taiwan

(1) Taiwan's existing warning system can only show which area had higher risk of sediment disaster during typhoons or heavy rainfall. It cannot clearly point out disaster will occur in which slope or torrent, and it also cannot present which types of sediment disaster will occur. So even if the local government receives the alert, it is still difficult to carry out evacuation[3].

(2) Taiwan's existing warning system is based on the model that depends on whether the rainfall exceeds the CL. However, the model cannot definitely describe the relationship between the rainfall and the disaster scale. Therefore, even if the rainfall is predicted to be 1,000mm or 2,000mm, the existing warning model cannot tell the difference and the severity of potential disasters.

(3) According to the statistics from Typhoon Morakot in 2009 in Taiwan, 60.9% of the sediment disasters occurred in the difficult period of evacuation (from 21:00 to 07:00)[1], so the appropriate timing of issuing alert should be before the sunset and retain enough time of evacuation.

(4) Sediment disaster warning model can only provide the possibility of disaster. The decision on evacuation needs to consider other issues, such as the locations, traffics and communications, shelters' location and the capacity, and people's capability of disaster resistance. However, a good warning system which can offer more accurate long-time predictions (for example, the next 12 hours) will be able to enhance local government's evacuation decision-making ability effectively.

5. CONCLUSIONS

Although Taiwan's existing warning system provide simple-to-apply criteria, the current systems cannot indicate the location, scale, type, and possible magnitude of the disasters. To improve the warning system, it is recommended to use the village extent as key areas. The major monitoring in the key areas should focus on the slopes which probably can damage the traffics and lifelines. New warning indexes are also recommended to consider both the geological and hydrological characteristics of the monitored slopes. Therefore, the existing warning system can be used as a warning system for large-scale response, and the new warning indexes can be used to develop a more detail, slope-scale warning system to improve the warning accuracy and enhance local government's evacuation decision-making ability effectively to reduce the possibility of casualties.

Keywords: warning system, sediment disaster, debris flow, slope failure, evacuation

References

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