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Identifying Rainfall Threshold for Triggering Landslide in Halong City Based on the Empirical Approach

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1. Introduction

Vietnam is one of the countries that have been deeply affected by natural hazards and climate change. Especially, mountainous areas normally suffer abnormal weather phenomena causing many extreme rainfall events and increasingly promote the process of geohazards. Landslides are among the most dangerous geohazards in Vietnamese mountainous regions that cause not only damage to environment and infrastructure but a huge threat on human life. This trend results to the urgent requirements of timely and effective works in order to prevent and mitigate the damage. In this research, we identify empirical rainfall thresholds and combine with forecasted rainfall to establish a landslide early warning system.

2. Study area

The pilot area is Halong City (Quang Ninh province) where a great fluidized swam-landslide disaster occurred in July 2015. Halong City is located in the center of the province with the complex and diverse topography including mountain, delta, coastal and island. The North and North East are covered by mountain containing 70% city's area, the average altitude ranges from 150-250 m, the highest is 504 m. The mountains are seaward lower. The slope of topography is 15-20^{o}.

3. Methodology and preliminary results

The empirical approach is applied to identify rainfall thresholds by analyzing historical rainfall events which triggered landslides. The rainfall data with different temporal resolution: daily rainfall data from 1961 to 2010, hourly rainfall data in rainy seasons (May - October) from 2011 to 2015 and 6 hours rainfall data in 2016 rainy season were collected from Bai Chay national hydro-meteorological station (located in the middle of Halong City). In the area, from 2005 to 2016, there were 16 rainfall-triggered landslide events reported with exact dates of occurrences (all in the rainy season), in which the data from 2005 to 2014 were used for calibration, and the data in rainy seasons of 2015 and 2016 were used for validation.

Values of landslide-related rainfall: Daily rainfall (R), daily rainfall intensity (I), maximum rainfall intensity (Imax), rainfall duration (D), cumulative event rainfall (E) and 3, 5, 10, 20, 30, 60, 90, 120 days antecedent were extracted and analyzed. Results show that maximum rainfall intensity (daily and hourly) and cumulative event rainfall have high correlations with landslide occurrence while the relationship between the antecedent rainfall and landslides in study area could not be identified. The rainfall thresholds for triggering landslide in Halong City were identified: [T1: Imax (daily) > 105 mm and E > 180 mm] Or [T2: Imax (hourly) > 54 mm and R > 74 mm] (Figure 1 and Figure 2).

To validate these rainfall thresholds, rainfall data in 2015 and 2016 were used in combination with landslide events recorded by field survey. There were two rainfall events exceed the threshold T1 and both events induced landslides in Halong City, while one in two rainfall events exceeding threshold T2 caused landslide initiation. Moreover, there were no landslides reported with rainfall events which were below the thresholds.

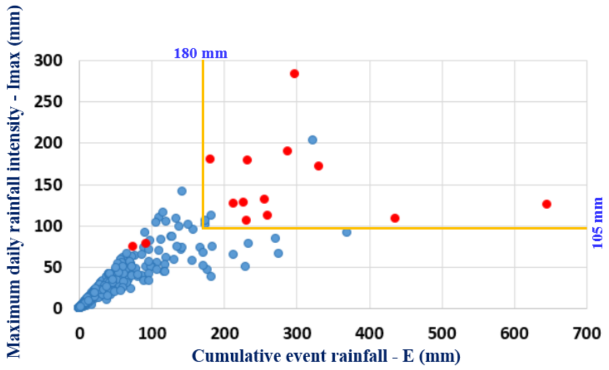

Figure 1: Relationship between maximum daily rainfall intensity-Imax and Cumulative event rainfall-E

(Landslide and rainfall data from 2005 to 2014)

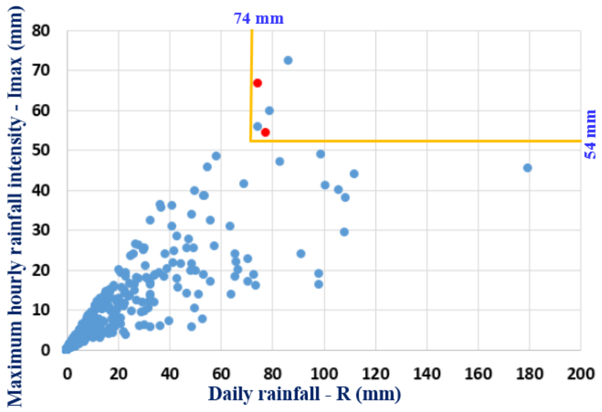

Figure 2: Relationship between maximum hourly rainfall intensity-Imax and Daily rainfall-R

(Landslide and rainfall data from 2005 to 2014)

In Figure1 and Figure2: Red-dot notations for the values with information of landslides, and the green-dot notations for the values without information of landslides.

To apply the identified thresholds for predicting the temporal occurrence of landslides in Halong City, we employ forecasted rainfall data from the Global Forecast System (GFS) - a weather forecast model produced by the National Centers for Environmental Prediction (NCEP) – USA (URL1). The GFS weather data have 3 hours temporal resolution and the spatial resolution is around 28 km in the first week of forecasted period. Authors employ IDV software (Unidata,2016) and Jython script to automatically access newly updated data from GFS server through OPeNDAP protocol and check whether the rainfall thresholds are exceeded or not. Figure 3 introduces the framework of an automatic system for updating GFS forecasted precipitation.

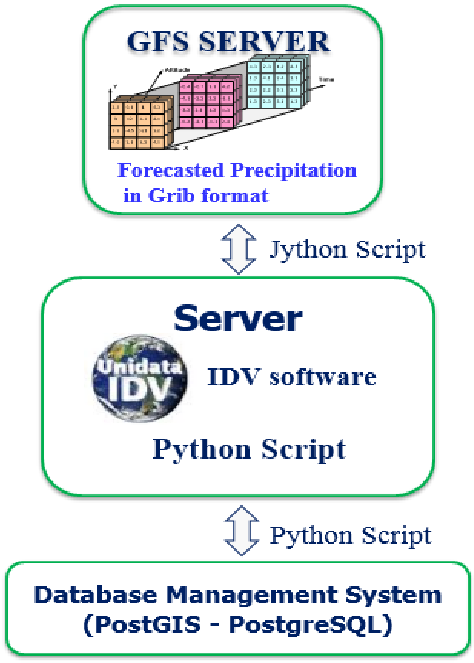

Figure 3: The framework of automatic system for updating GFS forecasted precipitation.

4. Conclusion

This study presents our preliminary results in identifying rainfall thresholds for triggering landslide and establish an early warning system for Halong City.

To improve the threshold accuracy, it is necessary to collect more adequate data of the past events, especially the exact time of landslide occurrences.

The identified thresholds are in accordance with the actual situations of the landslide occurrences in Halong City. Thus, the methodology can be improved to obtain more accurate thresholds for this case study area with more supplementary data and can be applied to other places with suitable adjustments.

5 References

Unidata, (2016): Integrated Data Viewer (IDV) version IDV_5.1 [software]. Boulder, CO: UCAR/Unidata.(http://doi.org/10.5065/D6RN35XM)

URL1:https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forcast-system-gfs