

TRIGRS Application for landslide susceptibility mapping

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Abstract. Research on landslide susceptibility has been carried out using several different methods. TRIGRS is a modeling program for landslide susceptibility by considering pore water pressure changes due to infiltration of rainfall. This paper aims to present a current state-of-the-art science on the development and application of TRIGRS. Some limitations of TRIGRS, some developments of it to improve its modeling capability, and some examples of the applications of some versions of it to model the effect of rainfall variation on landslide susceptibility are reviewed and discussed.

1. Introduction

Landslide disaster is a natural event that often occurs in hilly areas, especially in rainy seasons. It can cause damage of nature, damage of infrastructure, and victim. Therefore, research on landslide susceptibility mapping study is the most noteworthy used to minimize damage and loss of life. Studies on landslide susceptibility mapping are disaster risk reduction measures of landslide to predict the landslide event and prevent the threat of landslide in the future.

The Transient Rainfall Infiltration and Grid-Based Regional Slope-Stability Analysis (TRIGRS) is essential for landslide susceptibility mapping study. TRIGRS generates more satisfactory results than other landslide susceptibility analysis models, for example, SINMAP (Stability INDEX MAPping) [1]. TRIGRS model is ideal for landslide hazard zoning for land-use planning on a regional scale [1,2]. It is suitable for landslide susceptibility mapping study in Indonesia. TRIGRS is capable of reproducing the frequency of the size of the patches of terrain predicted as unstable by the model [3]. TRIGRS used for the landslide ratio of each predicted FS class (hereafter LR class) is employed for evaluating the unstable slope basins under various rainfall conditions [3]. TRIGRS model is a powerful tool for decision makers on susceptibility mapping, especially if integrated with numerous advanced applications using Geographic Information System (GIS) spatial functions [4].

TRIGRS model is a Fortran program designed for modeling landslide susceptibility by combining an infinite slope stability calculation and an analytic, one-dimensional solution for pore-pressure diffusion in a soil layer of finite depth in response to time-varying rainfall [5]. The TRIGRS analysis has been successfully used by [2,4,6-14]. TRIGRS model was used to evaluate regional shallow landslide susceptibility in a GIS framework [7-10]. This paper aims to present a current state-of-the-art science on the development and application of TRIGRS. Some limitations of TRIGRS, some developments of it to improve its modeling capability, and some examples of the applications of some versions of it to model the effect of rainfall variation on landslide are reviewed and discussed.

2. Limitations of TRIGRS

The TRIGRS model has limitation, i.e., being very slow in computation process when using high-resolution DEM (Digital Elevation Model), detail parameters, rainfall intensity, and long duration



pattern. The more details provided as inputs the longer is the running time of the code, mainly because the time needed to process the additional details into the program [13]. The operation of TRIGRS has problems. First, initialization file in TRIGRS.INI must contain no mistake before being run in TRIGRS. To change a parameter, a user has to edit the initialization file using a text editor. If there is a data mistake, the system will cancel and restart the program. Secondly, TRIGRS is not completed by spatial visualization, so it needs GIS (Geographic Information System) to visualize the model result [14]. Besides, vegetation cover is not considered influencing the occurrence and movement of rainfall-triggered landslides in the TRIGRS model [1].

The performance of TRIGRS model and time-variant slope stability (TiVaSS) model in the prediction of rainfall-induced shallow landslides has been compared [15]. According to that investigation, TiVaSS showed slightly better performance than TRIGRS in predicting both the location and timing of the events for landslide early warning systems, additional physical-based slope stability models are essential for capturing the influences of rainfall recharge on subsurface hydrological behavior as well as soil mechanics in triggering landslides. Despite TiVaSS have some limitations on the lack of input data, but the predicted landslides by TiVaSS show a consistent agreement with the reality [16]. TRIGRS produces less accurate results [15].

3. Developments of TRIGRS

Based on the limitations, TRIGRS is very slow in computation process. Some researchers analyzed the different contributions of the various factors to the running time of the code in order to reduce the major time-demanding operations and parallelize the computing-intensive part of the code [13]. They have developed and applied TRIGRS model by parallelizing the four time-demanding execution modes of TRIGRS within the Message Passing Interface (MPI) framework. In addition to new features of the code, it outlines details of the parallel implementation and shows the performance gained with respect to the serial code. Results are obtained both on commercial hardware and on a high-performance multi-node machine; showing the different limits of applicability of the new code. So, the parallel version of TRIGRS drastically reduces the total running time when it is run on two very different machines and for all the four model execution modes.

TRIGRS MAP is used integrate TRIGRS in a GIS-based program. TRIGRS MAP is a new program, as a user interface, to operate TRIGRS more easily and visualize its results in a form of a map. TRIGRS using Matlab to build a software Matlab version of TRIGRS (MaTRIGRS) has been developed [10]. The research is to evaluate MaTRIGRS as a physically distributed landslide model to predict the spatiotemporal occurrences of the widespread landslides that were triggered by recording rainfall over Macon County in the Blue Ridge Mountains, North Carolina during Hurricane Ivan in 2004.

TRIGRS model was used to improve the understanding of initiation mechanism and triggering factors for landslide processes. It was done by performing comprehensive field investigations, monitoring rainfall patterns, and doing laboratory experiments [1]. The parameters in the TRIGRS model are topographic factors, soil engineering characteristics like strength properties and hydraulic parameters of the soil, and a cumulative rainfall as controlling factors [12]. The rainfall intensity, duration, and soil hydraulic diffusivity were measured to assess the effects of transient rainfall on the timing and location of landslides, by modeling the pore water pressure. All input parameter layers were acquired to present spatial analyses results in a GIS framework.

4. Application of TRIGRS

There are many research on the the applications several versions of TRIGRS in modeling the effect of rainfall variation on landslide susceptibility. Infiltration models for unsaturated flow as an option for estimating infiltration at the ground surface use a transient component which assumes the infiltration process that typically relies on one-dimensional vertical flow [7,8], with the temporal flux boundary condition and varying intensity and duration of rainfall events at the ground surface. This model used Richards equation to describe unsaturated vertical flow in response to the infiltration of water in the ground surface [17].

TRIGRS model was used to evaluate regional shallow landslide susceptibility in a Geographic Information System framework [7-11]. TRIGRS model is a practical approach for mapping the susceptibility of landslide and debris flow of each pixel in an area dependent on the resolution of DEM [4] and the precise geotechnical parameters [10]. It is used to predict shallow landslide rainfall-induced influenced by resolution of temporal rainfall variations [1-2,6,10,11].

The development and application of TRIGRS are more useful for landslide prediction for a certain precipitation threshold on a regional scale and it generates more satisfactory results [1]. TRIGRS model was used to improve the understanding of initiation mechanism and triggering factors for landslide processes. It was done by performing comprehensive field investigations, monitoring rainfall patterns, and doing laboratory experiments [1].

5. Conclusions

Many TRIGRS model is acceptable for landslide susceptibility mapping for disaster risk reduction measures of landslide to predict the event and prevent the threat of landslide in the future. TRIGRS model is ideal for landslide hazard zoning on a regional scale but it has some limitations. Even though TRIGRS model has been developed by some researchers, this model still needs more development to improve the performance and to make it more user-friendly. The difficulties in applying TRIGRS is the limitation on available data, such as slope angle, soil depth, and initial water table on a steep area. Therefore, it needs some modification to improve the input parameters on the landslide prediction. TRIGRS produces less accurate results, so this model should be developed by combining the parallel version between TRIGRS model, TiVaSS model, and TRIGRSMap. Hopefully a new TRIGRS that has high performance and is user-friendly which can accommodate data input parameters that is a lot and more detailed with shorter processing time and able to facilitate visualization result of modeling can be obtained.

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