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A review of the prediction methods for landslide runout †

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Abstract: Shallow landslides which are generally triggered by extreme precipitation events are increasingly becoming common in the world. Societies have had difficulty in keeping up with the exponentially rising shallow landslides in recent years. Despite considerable progress in engineering studies, shallow landslides continue to cause much damage in different areas of the planet. Therefore, runout analyses are becoming more and more popular to resilience the negative effects of shallow landslides. Runout analyses are such crucial parts of shallow landslide studies that researchers have been keen on contributing to the existing knowledge. Earlier research suggested that runout analyses can be studied with empirical-statistical and numerical methods. Although there exist numerous landslide runout studies related to empirical-statistical and numerical solutions, it is not yet encountered a comparison of empirical-statistical and numerical methods' advantages and disadvantages in the literature. This research presents an evaluation of the advantages and disadvantages of the runout analysis methods.

Keywords: Shallow Landslide; Runout Analysis; Empirical-Statistical Method; Numerical Method

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1. Introduction

Shallow landslides threaten to grow into a full crisis in many societies. The recent shallow landslides are forceful reminder that engineers should continue to strive for preparation of comprehensive hazard map. Runout distance is perhaps the most critical part of many tasks for which researchers are responsible in time of the preparation of the landslide hazard map. Runout analysis not just has a critical role in landslide hazard assessment but also be used remedial engineering applications such as barriers [1, 2]. Forecasting of the shallow landslide runout method is still debatable among the researchers in order to decide the most effective methods. There is no specific method used worldwide for runout analysis. It is possible to detect researchers have dealt with landslide runout using different methods. This paper aims to offer a critical point of view to compare the advantages of the runout distance methods of empirical-statistical and numerical and decide the most suitable method according to study needs.

2. Landslide Runout

Landslide runout distance is the travel distance of landslide by considering the path of the movement which evaluated in terms of the event's start and the end points [3]. Runout distance is also affected by characteristics of material, topography, land use and land cover etc. [3, 4]. Runout distance prediction is necessary to depict possible inundation areas and appraise risks [5]. Researchers examine runout distance prediction by applying some methods which are empirical-statistical and numerical (Figure 1). This paper was prepared by searching the literature which consider determining runout distance by applying these methods. Therefore, necessary knowledge had gained in order to compare and discuss both methods in terms of their advantages and disadvantages.

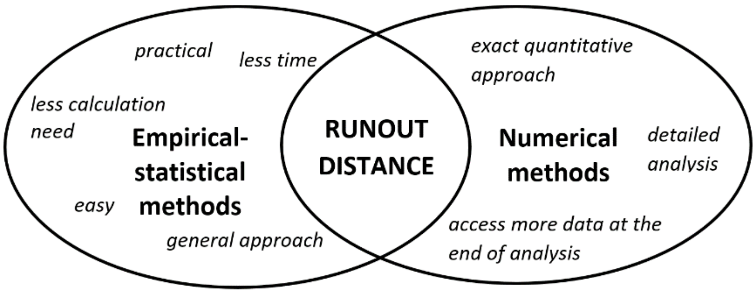

Figure 1. Runout distance prediction methods.

3. Comparisons of the Empirical-statistical and Numerical Methods

Empirical-statistical and numerical methods have a stated goal of assessing runout distance. Both methods provide clear opportunities to limit potentially disruptive risks. However, it needs to emphasize that as far as last studies concerned, the contestation of preference between empirical-statistical and numerical methods is maintained because of considering comparison of both benefits. A simple, publicly available model that can provide accurate results for researchers is often the ideal option for many important studies.

After much deliberation, the more useful method has been evaluated in this section. First, empirical-statistical methods are easy, practical, spending less time for computation, reaching general and simple approach, and less calculation requirement. Performing statistical analyzes are easy enough to be reproduced and applied in a reasonable time, while they are realistic at the same time. Evaluation results can be automated and generalized while results are evaluated and interpreted with care [6]. Therefore, these methods are more likely to be attempted to use because of not requiring a high level of expertise with respect to statistical knowledge. It should be noted that if sufficient data set about past landslide events from the field is provided, the future runout distance can be determined approximately by statistical methods [7]. In addition, it should not be neglected to emphasize empirical-statistical method disadvantages. It is undeniable fact that they evaluate the results approximately. Another drawback of these methods is that accurate assessments may not be possible in a complex environment. Because of neglecting of the initial material, there may occur conceptual confusion in empirical method [8]. In statistical methods, volume information is also not considered. For instance, debris flow volume may be more or less than real value in statistical methods [9, 10]. It is not easy with the naked eye to predict protruding and uneven areas on the modeled estimated surface [8]. Although statistical methods are powerful and easy, it may not be possible to develop a reliable empirical statistical correlation in the absence of sufficient data [11]. The statistical method's success in academic is based on an assessment of the plentiful data for shallow landslide analyses. Despite having comprehensive datasets, there may also be blunders in the results. Moreover, the utilization of software has increased for both method runout analyses because it offers realistic simulations, as well as increase the chance of acting against future dangers with their effective visual data. While DebrisFlow Predictor [4] and Flow-R [12] are empirical software in order to model runout distance, RAMMS [13], DAN3D [14], r.avaflow [15] and TITAN2D [16] are popularly used in numerical analyses studies. For example, Paudel et al. [17] preferred to choose empirical methods for debris flow runout analysis by utilizing the Flow-R software. Abraham et al. [18] and Bayissa [9] also used RAMMS software in order to model debris flow runout. Thanks to advance software, numerical runout evaluations have made tremendous progress in recent years so that they can provide opportunities to make a quantitative risk assessment. Additionally, numerical analysis simulations enable better characterization of the effect of the initial volume in simulations [6]. Not only do researchers examine runout areas in detail, but also, they access more data at the end of utilizing numerical methods. As far as more exact quantitative evaluation is concerned, numerical methods are undoubtedly much better than empirical methods. On the other hand, with respect to its time consuming, it is hard to mention the same thing. More time need to be allotted to the calculation of the runout distance in numerical analyses. Furthermore, numerical models offer the opportunity to examine in detail, but it can be a problem to work with these models in applications where rapid decision-making is required because it is difficult to obtain rheological parameters and take time to prepare simulations of all possibilities [6]. It is also very difficult to reflect the parameters taken from the field and required for numerical models in the laboratory environment [5]. Although there have been significant developments in runout analysis with numerical models in recent years; if precision of selection of model parameters is considered, it is difficult to model debris flow more realistically runout because it greatly affects the model results [5, 19-23]. Numerical models are complex, but at the same time their analyses are costly [24]. The fact that numerical analyzes are carried out by experts who are also experienced with respect to numerical analyses is one of the limitations of choosing these solutions [25].

4. Discussion and Conclusions

Even though numerical methods have many challenges, it is possible to come across many studies using numerical methods in the literature. It is clear that properly used, both methods will be highly effective considering the project requirements. For all the disadvantages of empirical-statistical methods, researchers know how to get by them and often prefer. Nevertheless, it is possible to assess that empirical-statistical methods are frequently better alternatives to reinforce runout analysis considering their advantages. Determination of shallow landslides runout distance is a serious global problem that require to researched. Rising demand about runout distance research causes to need determination of the more suitable method. Therefore, this research evaluates comprehensive summarization of the advantages and disadvantages of runout analyses inspire by researchers for addressing them in the foreseeable future. It also contributes to the comparison of runout methods for shallow landslide and highlights the high efficiency of empirical-statistical runout methods. It seems that empirical-statistical runout methods will continue to be preferred alternative methods to mitigate the shallow landslide hazards in the future of mankind.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: title; Table S1: title; Video S1: title.

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