proceedings

Proceeding Paper

A Review of the Prediction Methods for Landslide Runout [†]

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† Presented at the 4th International Electronic Conference on Geosciences, 1–15 December 2022; Available online: https://sciforum.net/event/IECG2022.

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 rate of shallow landslides in recent years. Despite the considerable progress made in engineering studies, shallow landslides continue to cause considerable damage in different areas of the planet. Therefore, runout analyses are becoming more and more popular ways of building resilience to the negative effects of shallow landslides. Runout analyses are such crucial parts of shallow landslide studies that researchers have been keen to contribute to the existing knowledge on the subject. 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, we had not 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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Citation: Komu, M.P.; Nefeslioglu, H.A.; Gokceoglu, C. A Review of the Prediction Methods for Landslide Runout. *Proceedings* **2023**, *87*, 3. https://doi.org/10.3390/IECG2022-14604

Academic Editor: Stefano Devoto

Published: 16 May 2023

1. Introduction

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

2. Landslide Runout

Landslide runout distance is the travel distance of landslide and is determined by considering and evaluating the path of movement in terms of the event's start and the end points [3]. Runout distance is also affected by the 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 that considers the determination of runout distance by applying these methods. Therefore, necessary knowledge had to be gained in order to compare and discuss both methods in terms of their advantages and disadvantages.

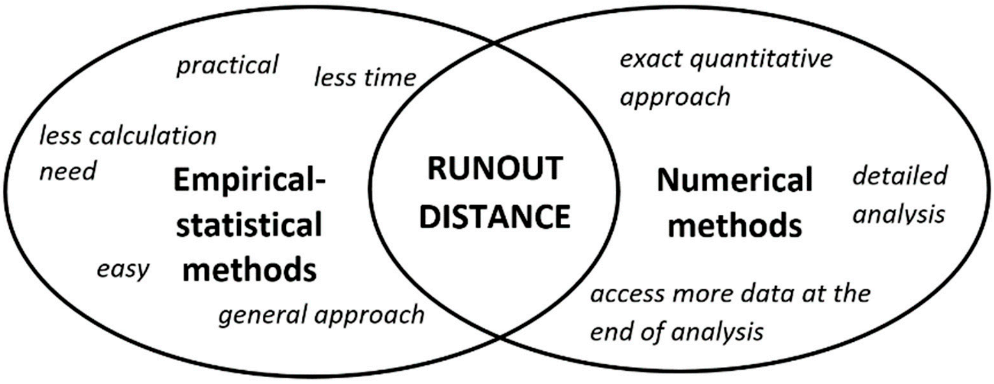

Figure 1. Runout distance prediction methods.

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 should be emphasized that as far as previous studies are concerned, the contestation of the preference between empirical–statistical and numerical methods is maintained because of the need to consider a comparison of the benefits of both. 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 out of the two has been evaluated, the results of which we present in this section. First, empirical–statistical methods are easy to use, practical, require less time for computation, have a general and simple approach, and come with less calculation requirements. It is easy enough to perform statistical analyses and reproduce and apply them in a reasonable time, although they are also realistic. The evaluation of results is automated and generalized, while results are evaluated and interpreted with care [6]. Therefore, researchers are more likely to attempt to use these methods because doing so does not requiring a high level of expertise with respect to statistical knowledge. It should be noted that if a sufficient data set is provided about past landslide events from the field, the future runout distance can be determined approximately by statistical methods [7]. In addition, it should not be neglected to emphasize the disadvantages of empirical–statistical methods. It is an undeniable fact that they evaluate the results approximately. Another drawback of these methods is that accurate assessments with them may not be possible in a complex environment. Due to the neglect 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 have a more or less than real value in statistical methods [9,10]. It is not easy to predict protruding and uneven areas with the naked eye on the modeled estimated surface [8]. Although statistical methods are powerful and easy to use, 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 applications is based on an assessment of the plentiful data available 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 methods of runout analyses because they offer 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 used 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 advances in software, tremendous progress has been made in numerical runout evaluations in recent years so that they can provide opportunities to perform quantitative risk assessments. 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 nature, it is hard to reach the same conclusion. More time needs to be allotted to the calculation of the runout distance in numerical analyses. Furthermore, numerical models offer the opportunity to make examinations 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 it takes 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 the precision of the selection of model parameters is considered, it is difficult to model debris flow runout more realistically because doing so greatly affects the model results [5,19–23]. Numerical models are complex, and 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, when 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 with them and often prefer them. Nevertheless, it is possible to assert that, considering their advantages, empirical–statistical methods are frequently better alternatives to reinforce runout analysis. Determination of shallow landslides runout distance is a serious global problem that must be researched. Rising demand for runout distance research causes us to need more suitable methods of determination. Therefore, inspired by researchers, this research provides comprehensive summarization of the advantages and disadvantages of runout analyses in order to address them in the foreseeable future. It also contributes to the comparison of runout methods for assessing shallow landslide phenomena and highlights the high efficiency of empirical–statistical runout methods. It seems that empirical–statistical runout methods will continue to be the preferred alternative methods with which to mitigate the shallow landslide hazards in the future of mankind.

Author Contributions: Conceptualization, C.G. and H.A.N.; methodology, H.A.N. and M.P.K.; investigation, M.P.K.; resources, M.P.K.; data curation, M.P.K.; writing—original draft preparation, M.P.K.; writing—review and editing, H.A.N.; supervision, C.G. and H.A.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: This work was produced from the Ph.D. thesis of Muge Pinar Komu, supervised by Candan Gokceoglu and Hakan Ahmet Nefeslioglu.

Conflicts of Interest: The authors declare no conflict of interest.

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