Landslides
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Training on the topic of landslides and slope stability in Rwanda: a Summer School in the framework of the Erasmus + EnRHEd project

Abstract From the 11th to the 16th of July 2022, a Summer School on "Landslides and Slope Stability Analysis in Rwanda" took place at Rwanda Polytechnic – College of Musanze (Rwanda). The Summer School was organized by the hosting institution (Rwanda Polytechnic – College of Musanze) in cooperation with the University of Parma (Italy), Rwanda Water Resources Board (RWB), and Rwanda Transport Development Agency (RTDA) in the framework of the Erasmus + EnRHEd project (https://enrhed-erasmusplus.com/). The EnRHEd project ("Enhancement of Rwandan Higher Education in strategic fields for sustainable growth") is co-funded by the European Commission and is coordinated by the University of Parma. Among the strategic fields for sustainable development, this project deals with "Environmental protection, safety, and management." In this domain, the topic of landslides plays a fundamental role, especially referring to the Rwandan context. It was the first time such a kind of Summer School on slope stability analysis took place in Rwanda. Besides the organizing institutions, the Summer School was supported by many other sponsors, like ICL – International Consortium on Landslides, AIGeo – Italian Association of Physical Geography and Geomorphology, IAH Italian Chapter – International Association of Hydrogeologists, Rocscience Inc., and the University of Parma.

Keywords Summer School · Landslides · Slope stability · Rwanda

The Rwandan context

Rwanda, which has an extension of 26,338 km^2 and a population of more than 12,000,000 inhabitants, has been recently affected by very intense rainfalls that caused a large number of both shallow and deep landslides with significant damage to structures, infrastructures, agricultural soil, and life losses (Nsengiyumva et al. 2018). Between 2000 and 2015, heavy rainfalls and landslides caused 108 deaths and ten thousand displaced and landless people, mostly in north and western provinces (Bizimana and Sonmez 2015). It has been estimated that the volume of debris from landslides was 110 million m^3, mainly deposited into rivers and streams and affecting the main roads (Bizimana and Sonmez 2015). The most frequent types are rainfall-induced shallow landslides on very steep slopes (Fig. 1). To reduce the occurrences of landslides, terraces have started being constructed by the government and local people. Afforestation is also being promoted everywhere to fight against landslide disasters, and some retaining walls have been built mainly against road-cut slopes (Valentino et al. 2021). Rwanda's vulnerability against hydrogeological risk needs to be adequately described in planning tools (Nsengiyumva and Valentino 2020). However, this kind of information would be fundamental in the policy of short-term management and emergencies. In fact, Rwanda still needs an up-to-date susceptibility map and appropriate cultural knowledge about landslides. Moreover, in Rwanda, there is a lack of knowledge concerning hydrogeological hazards, and scarce resources are allocated to guarantee the protection of life, goods, the natural environment, and human activities against landslides. On the other hand, the need for basic engineering-geological, geotechnical, geomorphological, and hydrogeological knowledge is growing, and methods to analyze slope stability at different scales should be developed in Rwandan higher education institutions.

About the EnRHEd project

The EnRHEd project (Project No: 609579-EPP-1–2019-1-IT-EPPKA2-CBHE-JP) was awarded in 2020 for EU co-funding within the framework of the Erasmus + program "Capacity Building in the Field of Higher Education," which supports the modernization, accessibility, and internationalization of higher education in partner countries, in this case, Rwanda.

The Summer School was strongly supported by all the seven partners of the EnRHEd project, namely, the University of Parma (lead institution), the University of Applied Sciences of Cologne (Germany), the University of Liege (Belgium), the University of Rwanda, Institute of Applied Sciences INES-Ruhengeri (Rwanda), Rwanda Polytechnic – IPRC-Musanze, and University of Technology and Arts of Byumba (Rwanda). The EnRHEd project aims to improve curricula and governance in the Rwandan partner institutions and strengthen relations between higher education systems.

The EnRHEd project includes two specific fields of interest for sustainable development: "Food science and technology" on the one hand and "Environmental protection, safety, and management" on the other. In these domains, the project has four ambitious objectives to achieve: (1) to support the

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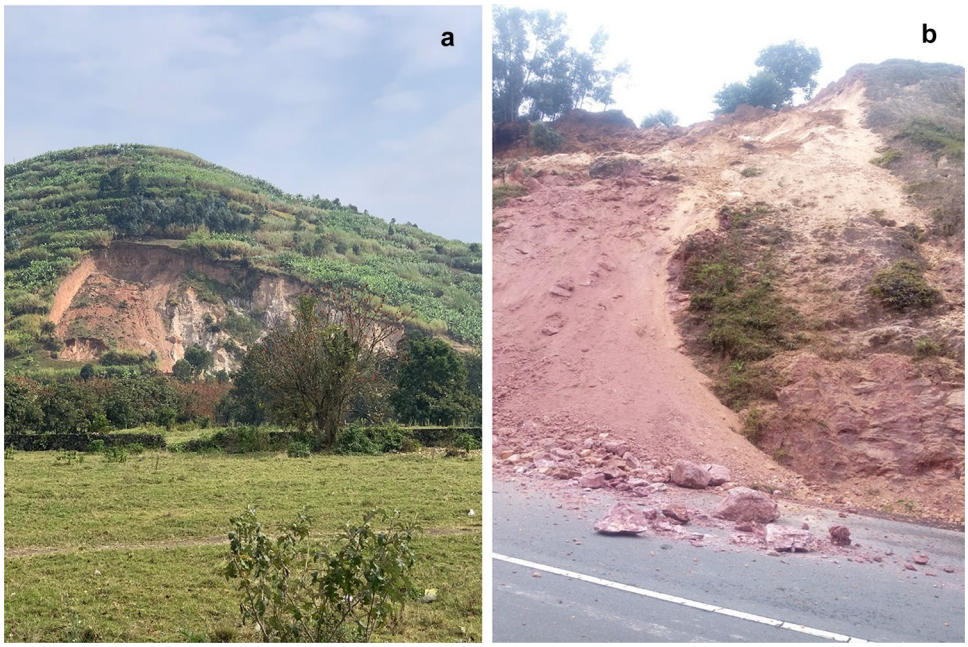

Fig. 1 Examples of typical landslides in Rwanda on a natural hill slope (**a**) and on a road-cut slope (**b**)

modernization of Rwandan partner institutions through the revision of the current programs and the improvement of the didactic approach, (2) to implement new degree and PhD programs, (3) to create a platform for digital didactics, and (4) to promote the internationalization of educational paths, by training the technical-administrative staff of Rwandan institutions. The activities of the project are mainly developed through the mobility of academic staff, administrative staff, and students between European and Rwandan institutions.

The main innovative character of the EnRHEd project to achieve its objectives is that all joint activities are carried out simultaneously at different levels of teaching and training in the two selected key fields of interest. Based on the advantage of working in these two specific domains, this project can be considered a pilot experimental methodology since it would be applied in the future in further fields of interest.

The Summer School

Taking into account the project framework and the Rwandan context, the EnRHEd team organized an international Summer School entitled "Landslides and slope stability analysis in Rwanda". The intention was to create a favorable opportunity to (1) establish a relationship between academia and public sectors in charge of civil works, (2) disseminate the "culture" of landslides and methodologies to approach the problem, and (3) present possible solutions to the slope instability. The main purpose of the Summer School was to train academics, professionals, and

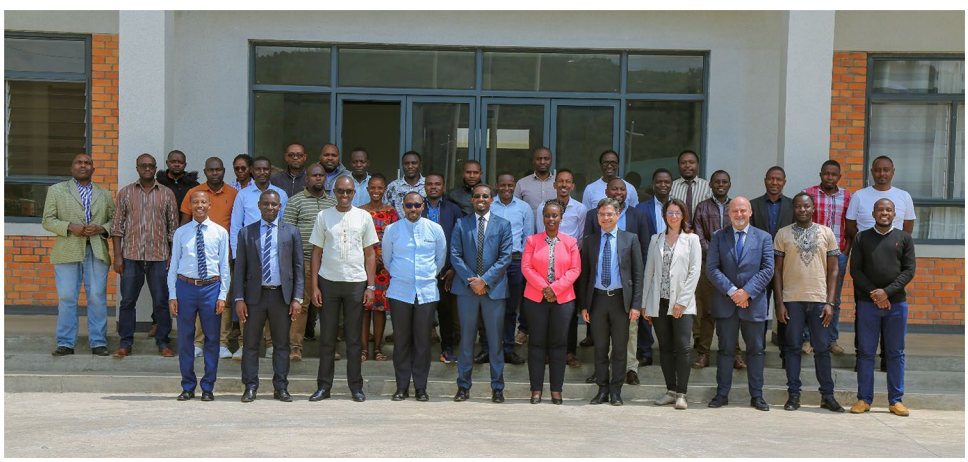

Fig. 2 Participants to the Summer School

practitioners in the "Environmental Protection, Safety, and Management" domain since landslides are considered a very urgent problem to be addressed in Rwanda. The participants were 31 (Fig. 2): 11 academics from higher education institutions, 3 from the Rwanda Water Resources Board, 1 from the Rwanda Transport Development Agency, and 16 from the local districts. The participants were mainly technicians, civil engineers, teaching staff, and practitioners involved in land management and protection at local public authorities. The Summer School had international relevance and proved a profitable opportunity to strengthen the collaborative relationships between the University of Parma and the Rwandan organizing institutions.

The main objectives of the Summer School can be summarized as follows: (i) improving the awareness of civil engineers, geologists, technicians, and teachers about the hydrogeological hazard in the Rwandan area; (ii) increasing the base knowledge of the main geomorphological, hydrogeological, and geotechnical processes connected with a landslide; (iii) bringing up the capability of tackling and solving slope stability problems using a commercial software; and (iv) introducing knowledge about problems connected with deforestation and solutions through replanting of soil slopes for stabilization purposes.

Three professors from the University of Parma were part of the teaching team (Fig. 3): Roberto Valentino, who dealt with the issue of slope stability from a geotechnical point of view; Alessandro Chelli, who highlighted the geomorphological aspects at various reference scales; and Emma Petrella, who focused on the hydrogeological aspects mainly related with the infiltration and flow processes in low permeability media affected by landslides. The Summer School also fulfilled transversal objectives, such as the transfer of knowledge on various approaches for the study of hydrogeological risk in the Rwandan territory, the transmission of skills suitable for the management of problems related to the stability of the slopes, and sharing of knowledge on topics such as data acquisition, laboratory and field tests, and methods useful for modeling slope instability phenomena.

After an opening ceremony, the Summer School started with a cycle of theoretical lessons during which basic concepts of geotechnics, geomorphology, and hydrogeology were taught. Therefore, several case studies at different scales, located in Italy and Rwanda, were presented and analyzed in terms of the monitoring network, description of involved processes, field investigation, and theoretical slope models. Finally, practical exercises were performed using appropriate numerical codes specifically designed for slope stability analysis. Some basic concepts related to the design of retaining structures were also introduced. The complete program of activities is reported in Table 1.

The Summer School has been a success beyond expectations, and all the people involved worked with enthusiasm and professionalism. The participants particularly appreciated the practice of the software (Fig. 4), which helped them in a better understanding of the basic concepts and the possible resolution of problems related to slope stability. During the concluding ceremony (Fig. 5), after receiving the attendance certificate (Fig. 6), all the participants proposed planning a second edition to improve the knowledge and skill acquired during this event.

Fig. 3 Teaching staff of the Summer School: Roberto Valentino, Emma Petrella, and Alessandro Chelli from the University of Parma (Italy)

Table 1 Program of the Summer School

Program of the Summer School "Landslides and slope stability analysis in Rwanda"		
Day	**Timing**	**Activity**
Monday 11/07/2022	08:30–09:00	Arrival of participants to the Summer School
	09:00–10:30	Introduction to the Summer School and general overview Prof. Roberto Valentino
	11:00–13:00	Basic concepts of geology and geomorphology connected to landslides Prof. Alessandro Chelli
	14:00–16:00	Basic concepts of hydrogeological aspects Prof. Emma Petrella
Tuesday 12/07/2022	08:30–10:30	Main characteristics of landslides and classification Prof.Alessandro Chelli
	11:00–13:00	Basic concepts of soil mechanics and stability of soil slopes – limit equilibrium methods Prof. Roberto Valentino
	14:00–16:00	Hydrogeological survey and monitoring network Prof. Emma Petrella
Wednesday 13/07/2022	08:30–09:45	Basic concepts of rock mechanics and stability of rock slopes Prof. Roberto Valentino
	10:15–11:30	Geological and geomorphological model of a slope Prof. Alessandro Chelli
	11:30–12:45	Hydrogeological processes in a landslide: case studies Prof. Emma Petrella
	14:00–17:00	Lab: Introduction to computer laboratory activities. Definition of the slope geometry through the use of SLIDE (Rocscience) Prof. Roberto Valentino
Thursday 14/07/2022	08:30–09:45	Field investigation and geotechnical model of a slope: case studies Prof. Roberto Valentino
	10:15–11:30	From the slope model to a basin scale model Prof. Alessandro Chelli
	11:30–12:45	A simple and effective tool to infer groundwater flow net Prof. Emma Petrella
	14:00–17:00	Lab: Slope stability analysis using SLIDE (Rocscience) Prof. Roberto Valentino
Friday 15/07/2022	08:30–10:30	Support methods and slope stabilization Prof. Roberto Valentino
	11:00–13:00	The geomorphological input to the slope stabilization Prof. Alessandro Chelli
	14:00–17:00	Lab: Design of supports using SLIDE (Rocscience) Prof. Roberto Valentino
Saturday 16/07/2022	08:30–12:30	Concluding ceremony

Fig. 4 Participants working on practical exercises during a session of the Summer School

Fig. 5 The closing ceremony

Fig. 6 Delivery of attendance certificates to a group of participants

Declarations

Conflict of interest The authors declare no competing interests.

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