Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 158 (2016) 541 – 545

Procedia Engineering

www.elsevier.com/locate/procedia

VI ITALIAN CONFERENCE OF RESEARCHERS IN GEOTECHNICAL ENGINEERING – Geotechnical Engineering in Multidisciplinary Research: from Microscale to Regional Scale, CNRIG2016

Modeling the effects induced by the expected climatic trends on landslide activity at large scale

Diana Salciarini[a,*], Evelina Volpe[a], Sara Alison Kelley[a], Luca Brocca[b], Stefania Camici[b], Giulia Fanelli[a], Claudio Tamagnini[a]

[a]*Department of Civil and Environmental Engineering, University of Perugia, via G. Duranti 93, 06125 (PG), Italy*
[b]*Research Institute for Geo-Hydrological Protection – National Research Council, via della Madonna Alta (PG), Italy*

Abstract

Traditionally, slope stability assessments are based on stationary expected extreme rainfalls, provided by the Intensity-Duration-Frequency curves. More recent approaches are based on projected rainfall scenarios, considering the expected climatic trends provided by General Circulation Models (GCMs). The projected rainfalls used in this study have been obtained by climate simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP5). Different GCMs emission scenarios (Representative Concentration Pathways 2.6, 4.5, 8.5) and time horizons (e.g., 2010-2039; 2040-2069; 2070-2099) are analysed. In order to fill the scale gap between the spatial resolution of GCMs and the resolution required for impact studies, statistically downscaled climate projections provided by [1-2] are used as input into PG_TRIGRS [3] to predict the effect of climatic change on landslide activity. A hydrological basin located in the Umbria region of central Italy is used as case study.

Peer-review under the responsibility of the organizing and scientific committees of CNRIG2016

Keywords: rainfall-induced landslides; climatic change; probabilistic models

1. Introduction

Rainfall-induced shallow landslides, triggered by heavy rainstorms, represent a major issue in the evaluation of

* Corresponding author. Tel.: +39-075-585-3957.
E-mail address: diana.salciarini@unipg.it

Peer-review under the responsibility of the organizing and scientific committees of CNRIG2016
doi:10.1016/j.proeng.2016.08.486

hazard at a territorial scale. The occurrence of landslides is controlled by several spatial and climatic factors. In particular, the occurrence of landslide reactivation is closely related to the intensity and duration of rainfall events. Given the predicted rainfall scenarios over a study area, the landslide activity can be assessed by means of different approaches. A quite promising one is based on the probabilistic physically–based model implemented in the code PG_TRIGRS [3], which takes into account the uncertainty in soil spatial variability and characterization. It is an extension of the original TRIGRS code [4-5] that combines a 1–D hydrologic model with a simple slope stability computation to assess the probability of slope failure over a large area.

Specifically, the considered extended code is based on: *i*) the Kriging geostatistical technique to establish characteristic or representative soil properties for the study area, starting from measurements at known locations. Kriging has also been used to define the synthetic indicators of the probability distribution for the selected random variables; and *ii*) the Point Estimate Method to evaluate the probability distribution of the safety factor F_s.

Traditionally, slope stability assessments are based on stationary expected extreme rainfalls, provided by the IDF (Intensity Duration Frequency) curves (see, i.e., the work by [6]). More recent approaches are based on projected rainfall scenarios, considering the expected climatic trends provided by General Circulation Models (GCMs). Since the spatial resolution of the climatic dataset provided by the GCMs is not directly applicable to practical cases at a regional scale, statistical downscaling methods have been adopted and applied to the climate projections (see, i.e., the work by [1] and [2]), obtaing RCMs (Regional Circulation Models). The aim of this work is to evaluate the effect of climatic change on landslide activity in a selected study basin.

2. The PG_TRIGRS model ([3])

PG_TRIGRS (Probabilistic, Geostatistic–based, Transient Rainfall Infiltration and Grid based Slope stability) is an extension of the original TRIGRS code developed by [4] for saturated soils, and later extended by [5] to unsaturated soil conditions. The new probabilistic version has been developed with the objective of providing an efficient yet accurate tool for wide area assessment of the probability of rainfall–induced failure, taking into account the spatial variability of soil properties over the study area along with their uncertainties.

Expressing pore water pressure on the failure surface in terms of pressure head $\psi = u/\gamma_w$, the Factor of Safety (F_s) of the slope with respect to translational sliding along the failure surface is given by:

$$F_S(Z,t) = \frac{\tau_f}{\tau_m} = \frac{\tan\phi'}{\tan\alpha} + \frac{c' - \gamma_w \psi(Z,t)\tan\phi'}{\gamma Z \sin\alpha\cos\alpha} \tag{1}$$

where α is the slope angle, ϕ' is the soil friction angle, *c*' is the soil effective cohesion, and γ is the unit weight of the soil. In transient flow conditions, the factor of safety varies with *Z* and *t*, due to the evolution in time and space of the pressure head ψ generated by the rainfall infiltration process.

PG_TRIGRS computes the Probability of Failure (PoF) of a given slope starting from the evaluation of the Factor of Safety (F_s) given by Eq. 1 for each considered permutation of the soil parameters expressed as random variables. In particular, 8 permutations have been considered and the PoF has been computed assuming a log–normal distribution for F_s.

3. The case study

The selected study area is located in the center of the Perugia province (Fig. 1a) and has an extension of 6x6 km^2. To evaluate the effect of climatic change on landslide activity using a spatially distributed, physically based model, it has been subdivided into 300x300 cells of 20 m side. The distribution of the soil types in the selected study is shown in Fig 1b.