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Prediction of shallow landslides in pyroclastic soils due to climatic changes in the Mediterranean area

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The paper reports the results of numerical simulations aimed to the individuation of a simple and rational procedure to investigate the effects of climate change on the behaviour of slopes in unsaturated pyroclastic soils affected by rainfall-induced landslides. The forecasting of the response of the Cervinara slope has been conducted, which was interested in a killer flowslide during 1999 and was monitored since 2002. The analyses have been performed using the hand-made code I-MOD3D for the study of seepage processes in unsaturated medium and stability analyses, which was firstly validated on a period two years long on the base of in situ suction and rainfall monitoring, and using as climatic boundary conditions the results of numerical analysis performed by the climate team of C.I.R.A. by using the COSMO-CLM climatic model. This is a non-hydrostatic Regional Climate Model (RCM) running with a horizontal resolution of around 10 km; within areas with complex orography, this is a useful tool for the description of the precipitation patterns and for the land morphology complexity. In fact a higher spatial resolution allows a better description of the valley/mountain elevations, that is one of the causes leading to errors in precipitation analysis. The non-hydrostatic feature allows to provide a good description of the convective phenomena which are generated by vertical movement (through transport and turbulent mixing) of the properties of the fluid as energy (heat), water vapour and momentum causing severe precipitation events (as thunderstorm or cluster of thunderstorm)..

The system COSMO-CLM has been developed by the DWD–Germany and the COSMO Consortium for weather forecast services. Subsequently, the model has been updated by the CLM-Community in order to develop also climatic applications. C.I.R.A. (Italian Aerospace Research Centre) is a member of the CLM community.

Predicting impacts of potential climate change on slope stability is complex. Impacts could be both negative and positive for warming climate scenarios, depending on storm pattern changes which are uncertain. On the base of this consideration, a group of researchers of Second University of Naples and of C.I.R.A. has investigated the effects of climate change on slope stability for the case of a slope covered by pyroclastic soils in Campania. These activities have been performed in the framework of the CMCC (Euro Mediterranean Centre for Climate Changes) FISR project. The CMCC FISR is a scientific research facility established five years ago with the aim to deepen the knowledge in the field of climate variability and in particular on its causes and consequences. In particular, C.IR.A. is the leader of the Impacts on the Soil and Coast (ISC) Division and is studying the impact of climate changes on terrestrial ,marine ecosystems, on coastal zones and the hydrogeological risk connected with meteorological events (as intensive rain).

One of the working groups of ISC division is focusing on the development of models, algorithms and software useful for the analysis of hydrological phenomena, such as landslides caused by extreme weather events

The proposed approach requires three main steps:

- the individuation of the main climate factors that influence the behaviour of the slope;
- the validation of both climatic and hydrological models used to evaluate respectively the future trend of rainfall and mean temperature and, in cascade, the future response of the investigated slope, on the base of measured suction data;
- the forecasting of the slope behaviour on the base of the future climatologic scenario.

The first step has been pursued on the base of literature case histories similar to the analyzed one and on a detailed study of the slope response, which reveals that the controlling factors of rapid shallow landslides in pyroclastic granular soils are essentially the heavy rainfall events and the antecedent 30-days precipitation, together with evapo-transpiration, which strongly affect the initial soil-moisture conditions.

To face the second step, it is essential to have a good and long series of experimental data in order to validate the numerical codes. In the case of climatic model COSMO-CLM the comparison between the results of analysis and experimental data for a 10-years long period (1996-2006) highlights that the model is able to capture the mean monthly temperature but heavily underestimates the annual precipitation, the most intense rainfall heights and

the number of rainy days: thus, this step revealed that an appropriate statistical correction of numerical data is necessary. On the other side, the validation of I-MOD3D code used for the analysis of infiltration process (made on the base of a 14 months-long period during 2006-2007 where experimental data from in situ monitoring were available) reveals that a fair agreement between numerical and monitored suction has been reached: this suggests that the code can be used as a tool for the assessment of the behaviour of the slope.

Moreover, an evaluation of the long-term behaviour of the investigated slope at the year 2060 has been done considering the climate scenario furnished over the next century by the climatic group of C.I.R.A. which indicates an increase in temperature, a decrease in annual cumulated precipitation and a substantial similar distribution of most intense rainfall events.

The combined effect of an increasing temperature, (promoting a stronger evaporation) and of a decreasing rainfall will lead to a reduction of net infiltration. This circumstance can affect the initial soil-moisture conditions increasing the mean values of suction: hence, since no variation seems to be attended in terms of intense rainfall events, the stability condition of the slope will globally increase over the years. However, this assessment of future scenario is strongly affected by the hypothesis done and has to be considered only as an attempt to utilize a procedure for predicting impacts of potential climate change on slope stability of shallow pyroclastic soil deposits.

The main goal of the ongoing research is the individuation of a simple and rational procedure to link weather-climate forecasting to the prediction of slope failure at a local scale. In general, for each kind of slope movements, this procedure requires: i) the individuation of the climate factors which can have influence on the slope response; ii) a good knowledge of the geomorphological context and of the geotechnical characteristics of the involved soils; iii) the validation of numerical models for both climatic change and slope stability forecasting; iv) the prediction of landslides activity basing on climate change. Despite of the simple procedure described here, the complexity of both climatic and geotechnical aspects and their interaction make the landslide forecasting a very hard task, as it is well known by the scientific community.