



Development of a soil moisture forecasting method for a landslide early warning system (LEWS): Pilot cases in coastal regions of Brazil

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ABSTRACT

Climate change has increased the frequency of extreme weather events and, consequently, the number of occurrences of natural disasters. In Brazil, among these disasters, floods, flash floods, and landslides account for the highest number of deaths, the latter being the most lethal. Bearing in mind the importance of monitoring areas susceptible to disasters, the REMADEN/REDEGEO project of the National Center for Monitoring and Natural Disaster Alerts (Cemaden) has promoted the installation of a network of soil moisture sensors in regions with a long history of landslides. This network was used in the present paper as a base to develop a system for moisture forecasting in those critical zones. The time series of rainfall and moisture were used in an inversion algorithm to obtain the geotechnical parameters of the soil. Then the geotechnical model was used in a forward calculation with the rainfall prediction to obtain the soil moisture forecast. The landslide events of March 2020 and May 2022 in Guarujá and Recife, respectively, were used as study cases for the developed system. The obtained results indicate that the proposed methodology has the potential to be used as an important tool in the decision-making process for issuing landslide alerts.

1. Introduction

Evidence of climate change has been observed in extreme events such as heatwaves, heavy precipitation, droughts, and tropical cyclones (IPCC. Intergovernmental Panel on Climate Change, 2023). Due to the nonlinearity in the occurrence of these episodes, the prediction of disasters is impaired, potentially increasing the impacts (Marengo et al., 2009). In Brazil, about 9 out of 100 inhabitants live in areas subject to disasters and approximately 3000 km² of the country's territory corresponds to areas susceptible to the disaster risk of climate events (Alvalá et al., 2019). Considering the projection of increase in extreme precipitation events, according to the Intergovernmental Panel on Climate Change (IPCC. Intergovernmental Panel on Climate Change, 2023), this number can increase if planning and management measures for disaster risk reduction are not implemented.

Floods, flash floods, and landslides are the natural disasters that cause the most deaths in Brazil (Marengo et al., 2023; De Assis Dias

et al., 2018). Among these, landslides are the most common type and cause more deaths. A landslide is a nonlinear dynamic system that is affected by a variety of factors (Huang et al., 2023) as geological, geomorphological, climatic, and hydrological aspects, and vegetation characteristics or conditions, as well as land use and land cover (Tominaga et al., 2015). In addition, the irregular urban sprawl and the settlements in inappropriate locations, especially by the poor sector of the population, have increased the number of landslide events that cause human and material losses (Bortolozo et al., 2018, 2019). Thus, the landslide disaster risks arise from a combination of physical processes and social processes exposing certain groups in society to the potentially damaging effects thereof (Mendonça and Silva, 2020).

Specifically, the Brazilian coast has a higher occurrence of mass movements due to the steep terrain and high rainfall indices (Deborteli et al., 2017; Silva et al., 2021), associated with geological characteristics and anthropic interference on the environment. In this perspective, certain areas of the Northeast region of Brazil, mainly the states of

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