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Rainfall thresholds for the initiation of shallow landslides in the Wiśnicz Foothills region (the Flysch Carpathians Mountain, Poland)

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Determination of the magnitude of the rainfall threshold is a complex task, as it depends on the properties of the engineering-geological formations deposited on slopes and lithological conditions; it is also a resultant of the intensity and duration of precipitation. Meteorological monitoring and knowledge of the geological structure and adequate engineering tools (models of the soil and rock substrate) can greatly contribute to identification of the magnitude of rainfall that can pose a threat to slope stability. Calculation programs, which include the physical description of changes in the stress state in the soil substrate, are widely used tools for assessment of the slope stability conditions. Such programs take into account only the impact of rainfall on slope stability conditions and disregard the role of other meteorological factors. Development of a model that would be able to estimate these values is difficult; hence, this paper presents an attempt to determine the impact of precipitation on slope stability of selected shallow landslide slopes located in the area of the Wiśnicz Foothills (Outer Carpathians, Poland) using physically-based model taking into account meteorological conditions.
Firstly, based on the meteorological data from 2004-2013 calculations of slope stability were performed to verify the geotechnical parameters of the soils. The calculations also yielded the range of pore pressure changes in the analysed period of 2004-2013, which simultaneously facilitated determination of extreme slope stability conditions prevailing during the growing seasons in the analysed years. Further investigations were focused on determination of changes in slope stability induced in response to 120-day long rainfalls with increasing, constant, and decreasing intensities characterised by a 1-99% probability of occurrence. For the analysis, three systems of pore pressure distribution in the slope were employed. Two of them corresponded to the maximum and minimum soil wetness values at the beginning of the growing seasons in 2004-2013 (period between late March and late July, which substantially coincides with periods of intensification of mass movements in Polish Flysch Carpathians).
The analyses were performed with the calculation modules of the GeoSlope Inc. package:
- Vadose/W was used to determine the impact of meteorological conditions (temperature, humidity, wind speed, precipitation) on the pore pressure distribution in the slope,
- Slope/W - calculations of slope stability.
The stability calculations have confirmed that the rainfall threshold values are a function of many variables, primarily the hydraulic properties of slope covers and rock substratum, temporal distribution of precipitation, and wetness conditions (degree of slope cover saturation). The major mechanism of stability failure by the analysed slopes in the Wiśnicz Foothills is the saturation of slope covers. Given this mechanism, observations of the groundwater table can be an important factor in assessment of the susceptibility of slopes to mass movements, besides meteorological observations. It also seems that slope stability calculations can be an important tool for assessment of landslide hazards. Importantly, the calculations have to take into account not only precipitation data but also other meteorological factors, which have impact on the amount of water accumulated in slope covers.