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A conceptual approach to approximate tree root architecture in infinite slope models

Elmar Schmaltz and Thomas Glade

University of Vienna, Institute of Geography and Regional Research, Department of Geomorphological Systems and Risk Research, Vienna, Austria (elmar.schmaltz@univie.ac.at)

Vegetation-related properties – particularly tree root distribution and coherent hydrologic and mechanical effects on the underlying soil mantle – are commonly not considered in infinite slope models. Indeed, from a geotechnical point of view, these effects appear to be difficult to be reproduced reliably in a physically-based modelling approach. The growth of a tree and the expansion of its root architecture are directly connected with both intrinsic properties such as species and age, and extrinsic factors like topography, availability of nutrients, climate and soil type. These parameters control four main issues of the tree root architecture: 1) Type of rooting; 2) maximum growing distance to the tree stem (radius r); 3) maximum growing depth (height h); and 4) potential deformation of the root system. Geometric solids are able to approximate the distribution of a tree root system.

The objective of this paper is to investigate whether it is possible to implement root systems and the connected hydrological and mechanical attributes sufficiently in a 3-dimensional slope stability model. Hereby, a spatio-dynamic vegetation module should cope with the demands of performance, computation time and significance. However, in this presentation, we focus only on the distribution of roots. The assumption is that the horizontal root distribution around a tree stem on a 2-dimensional plane can be described by a circle with the stem located at the centroid and a distinct radius r that is dependent on age and species. We classified three main types of tree root systems and reproduced the species-age-related root distribution with three respective mathematical solids in a synthetic 3-dimensional hillslope ambience. Thus, two solids in an Euclidian space were distinguished to represent the three root systems: i) cylinders with radius r and height h, whilst the dimension of latter defines the shape of a taproot-system or a shallow-root-system respectively; ii) elliptic paraboloids represent a cordate-root-system with radius r, height h and a constant, species-independent curvature. This procedure simplifies the classification of tree species into the three defined geometric solids. In this study we introduce a conceptual approach to estimate the 2- and 3-dimensional distribution of different tree root systems, and to implement it in a raster environment, as it is used in infinite slope models. Hereto we used the PCRaster extension in a python framework.

The results show that root distribution and root growth are spatially reproducible in a simple raster framework. The outputs exhibit significant effects for a synthetically generated slope on local scale for equal time-steps. The preliminary results depict an initial step to develop a vegetation module that can be coupled with hydro-mechanical slope stability models. This approach is expected to yield a valuable contribution to the implementation of vegetation-related properties, in particular effects of root-reinforcement, into physically-based approaches using infinite slope models.