Analysis of the stability of a forest slope

Numerical analysis of the stability of a forest slope integrating the spatio-temporal dynamics of the stand

ABSTRACT

This project has set up a battery of digital tools and 2D and 3D models (based on the finite element method, FEM) to analyze in a generic way the influence of vegetation on slope stability. These tools and models take into account the mechanical effects (soil reinforcement by roots) and water (influence of roots on soil hydraulic conductivity and water status of the slope). They have been used in studies conducted in Togo (unpublished results) and on the Loess Plateau in China (results under publication).
The actions undertaken concern the following:
Action 1 - Development of a library of tools (under the form of Python scripts) in the computer code Abaqus FEA to model a forest slope and determine its degree of stability. This library consists mainly of: 1 - a generic builder of slope geometry that can set a rectilinear slope (profile, angle, height, ...) and associate its physico-mechanical properties, 2 - a generator which allows to set the geometry and properties of root compartments depending on the species (represented by half-sphere, cylinder or cone; dimensions; associated additional cohesions) and distribute the trees on the slope according to regular (rows of trees) or random patterns; 3 – a manager of analyses, which can run successive simulations to determine the safety factor (cohesion reduction method) and to perform sensitivity studies to different geometrical and mechanical parameters, 4 - a data extractor to determine the safety factor of the slope, the depth of the slip surface and the volume of soil mobilized from simulation results;
Action 2 - Development of a module to read root data (field data, extraction of simulation results the plant architecture simulator AMAPsim, ...) from a domain discretized in space voxels. This tool allows defining continuous maps of additional cohesions (via root densities) that will overlay the original properties of the bare soil at scales of the individual or the slope. This work is still in progress and future results will be published.
Action 3 - Numerical analyses of the impact of various reforestation scenarios on slope stability, taking into account the morphology and size of the root systems, as well as the structure and density of the stand. The model and the results of numerical analyses have been the subject of an article accepted in Ecological Engineering. The results were used to quantify the relative roles of root characteristics and planting patterns on the soil reinforcement.
Action 4 - Consideration of hydrologic factors in the numerical model. Equations of water flow and soil mechanics have been coupled for the analysis of slope stability. The ultimate goal is to take into account the effect of vegetation on the water regime of the slope and its relative impact on the safety factor. This work is being finalized as part of the thesis of Miss Jinnan Ji (co-tutelle Université Montpellier 2, Beijing Forestry University), 2008-2011).
Action 5 – Application to case studies in Togo and China. Field studies were conducted in Togo and on the Loess Plateau in China (Ji Jinnan thesis). They aimed to quantify and spatialize rooting properties (biomass, root number, root area ratio "RAR) in the context of monoculture forests. These data were supplemented by tensile tests conducted in the laboratory and used to calculate the additional cohesion. This information was then integrated into the simulator of slope stability to quantify their contribution to increasing the safety factor. The measurement campaign conducted in China has also identified correlations between root density and soil hydraulic conductivity. These results will help calibrating the hydrological model developed as part of the Jinnan Ji’s thesis (see action 5).
Action 6 - Establishment of new collaboration projects (Master, PhD thesis, Interuniversity Scientific Cooperation Project AUF) and reinforcing partnerships: Support to this RTRA project and framework for continued works with the University of Lomé (Faculty of Science, Agronomy Faculty, National School of Engineers), the Beijing Forestry University and the University of Abomey Calavi (Bénin).

Keywords : Agroecosystem, Method/tool/technic, Model, Scenario, Eucalyptus, Root

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