Geophysical Research Abstracts
Vol. 19, EGU2017-14475, 2017
EGU General Assembly 2017

Linking plants, fungi and soil mechanics

Anil Yildiz (1,2,3) and Frank Graf (4)

(1) WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland (anil.yildiz@slf.ch), (2) Swiss Federal Institute for Forest, Snow and Landscape Reserch WSL, Birmensdorf, Switzerland, (3) ETH Zurich, Zurich, Switzerland, (4) WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland (graf@slf.ch)

Plants provide important functions in respect soil strength and are increasingly considered for slope stabilisation within eco-engineering methods, particularly to prevent superficial soil failure. The protective functions include hydrological regulation through interception and evapo-transpiration as well as mechanical stabilisation through root reinforcement and, to a certain extent, chemical stabilisation through sticky metabolites. The ever-growing application of plants in slope stabilisation demanded more precise information of the vegetation effects and, concomitant, led the models for quantifying the reinforcement shoot up like mushrooms. However, so far, the framework and interrelationships for both the role of plants and the quantification concepts have not been thoroughly analysed and comprehensively considered, respectively, often resulting in unsatisfactory results.

Although it seems obvious and is implicitly presupposed that the plant specific functions related to slope stability require growth and development, this is anything but given, particularly under the often hostile conditions dominating on bare and steep slopes. There, the superficial soil layer is often characterised by a lack of fines and missing medium-sized and fine pores due to an unstable soil matrix, predominantly formed by coarse grains. Low water retention capacity and substantial leaching of nutrients are the adverse consequences. Given this general set-up, sustainable plant growth and, particularly, root development is virtually unachievable.

At exactly this point mycorrhizal fungi, the symbiotic partners of almost all plants used in eco-engineering, come into play. Though, they are probably well-known within the eco-engineering community, mycorrhizal fungi lead a humble existence. This is in spite of the fact that they supply their hosts with water and nutrients, improving the plant's ability to master otherwise unbridgeable environmental conditions. However, in order to support their plant partners, the fungi themselves need to have access to water and nutrients. For this purpose, a resilient soil matrix consisting of stable micro- and macro-aggregates is an indispensable prerequisite. Luckily, the fungi are among the pioneers in assembling stable aggregates. The fungal hyphae intensively penetrate the unstructured soil body, enmeshing small organic and inorganic soil particles and form and cement them to micro- and macro-aggregates.

On the one hand, growing hyphae are able to align primary particles and, on the other hand, exert pressure on surrounding particles and compounds forcing them together, such as clay and organic matter. Under physiological (or neutral) pH values, the fungal mycelia have a net negative charge. It is suggested that negatively charged fungal polysaccharides are bound to negatively charged clay minerals by bridges of polyvalent cations which have been proven to be stronger than some direct bonds between clay and organic matter.

The formation of aggregates up to a size of 2 mm is associated with hyphal length of fungi. With regard to the assemblage of aggregates >2 mm both fungal mycelia and roots are involved. Indirectly, the mycorrhizal fungi affect the aggregate establishment through their host plants, particularly by accelerating the development of their root network and by serving as a distribution vector for associated micro-organisms, mainly bacteria and archaea, additionally contributing to cementation. Therefore, root-reinforcement as addressed for quantification of vegetation effects on slope stability almost ever is a combined contribution of fungal mycelia and root networks. With soil aggregates as the "bricks" for building a stable soil matrix and pore structure, root-reinforcement strongly depends on aggregate strength controlling potential, efficiency, and sustainability of growth and development of the protective vegetation.

From a geotechnical point of view, aggregation of fines may be such pronounced that characteristics of coarse-grained soils are adopted, often mirrored by higher values of the shear strength parameters, particularly the angle of internal friction Φ'. Consequently, neither the positive relationship between the strength of soil aggregates and slope stability is astonishing nor is the positive correlation between root characteristics – architecture represented by 3^D-complexity, specific length and its density – and factor of safety calculations related to superficial soil failure. As far as the latter is concerned, however, so far almost exclusively the common shear strength parameters have been considered, namely angle of internal friction Φ' and root cohesion c'. However, similarly to the way

fungi were ignored in biological slope stabilisation, the soil mechanically relevant parameter dilatancy (Ψ) was not in the concepts and modelling approaches for quantifying root-reinforcement. Nevertheless, dilatancy (Ψ) is an important mechanism and a contributing factor to the shearing behaviour of root-permeated soil that definitively cannot be ignored. Such evidence is soundly based on the fact that specific root characteristics combined with the maximum dilatancy angle (Ψ_{max}) can explain the most variation in peak shear strength parameters.

Therefore, a combined approach including soil, fungi, and roots under consideration of dilatancy is a promising way towards better understanding and more reliably quantifying the shear strength of root-permeated soil. Since sound quantification of biological stabilisation effects is the key for both sustainable slope stabilisation and wide acceptance of eco-engineering measures within the scope of risk and hazard prevention.