NRP 68: Soil stability and natural hazards - from knowledge to action

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Advisory Board: Representatives of Private Sector (Consulting, Construction Support), Federal (BAFU) and Cantonal (GR, NW) Administration, Professional Associations (FAN, VIB), Universities (Basel, Delft, Milano), and Universities of Applied Sciences (Bern, HAFL)

Abstract: Within Module 1, we aim to quantify biological effects on soil and slope stability. Early-warning indicators for the susceptibility of slope failure are spatially addressed in Module 2. Based on both of these, we want to compile a concept for sustainable soil use and ecological restoration that balances stability, diversity, and land-use (Module 3). First results indicate that slopes meeting all the following requirements are able to withstand heavy rainstorms, such as the extreme event in 2005: (i) slope inclination not exceeding the angle of internal friction Φ' of the soil in the slope by more than ~5°, (ii) more than 50-70% of natural vegetation cover within succession paths to the target association e.g. NaiS for forests, (iii) particularly on steep terrain no gaps (in forests) longer than ~25 m and, (iv) in the case of re-stabilisation measures (eco-engineering), starting from applying site adapted plants associated with naturally compatible mycorrhizal fungi under consideration of relevant succession processes and necessary management and maintenance.

Module 1 (Quantification of biological effects on soil and slope stability)

Direct shear tests demonstrate a distinct increase in the maximum shear force from 10 to 65% in planted samples compared to non-planted soil (Fig. 1). Analysis of the reinforcing effect of roots and mycorrhiza might help to explain the large variance [1]. Additional positive correlations were found between soil aggregate stability, root growth, and mycorrhization in laboratory as well as field experiments (Figs. 2-4). Of particular importance could prove the similar relative increase in soil aggregate stability (Fig. 2) due to mycorrhized plants after a growth period of about 25 weeks and 25 years under lab and field conditions, respectively [2,3]. This correlation may open up a new way to up-scale results from the lab to nature, supporting the spatial approach in Module 2.

The positive effects of suited mycorrhizal fungi on plant growth and soil aggregate stability become apparent almost immediately (within 1st vegetation period) and increase in the course of time [2]. However, it was found that application of less specific (commercial) inoculi results in a delay of such effects developing only during the 2nd and 3rd vegetation period [4,5], although promptly influencing survival and/or preparing the natural mycorrhization of more efficient fungi as was found for *Cenococcum geophilum* L. [6]. Further investigation is planned in **collaboration with M. van der Heijden *et al.* (NRP 68)**.

Close **collaboration has been established with the EU project REVENUES**, using PFC3D, to model roots and soil aggregate stability numerically [3,7] allowing coupling with traditional slope failure approaches.

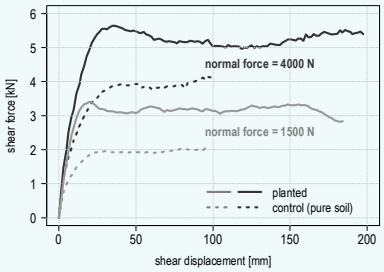

Fig. 1: Peak shear force depending on treatment (planted, pure soil) and Normal force.

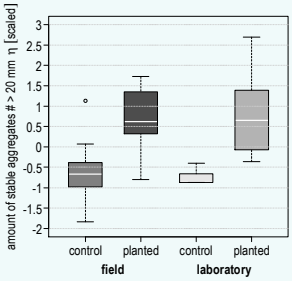

Fig. 2: Relative increase in soil aggregate stability in the field (25 years) and lab (25 weeks).

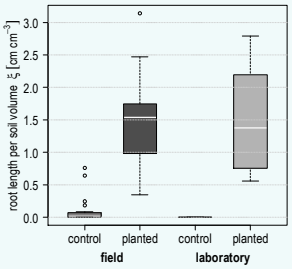

Fig. 3: Root development in the field (25 years) and lab (25 weeks) experiments.

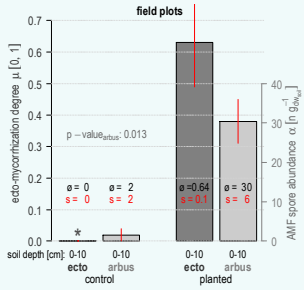

Fig. 4: Mycorrhization development in the field 25 years after application of eco-engineering.

Module 2 (Spatial application of early-warning indicators for susceptibility of slope failure)

Analysis of variables characterising forest structure confirms their influence on susceptibility of shallow landslides. Models based on "ground truth" perform much better than those derived from LiDAR data and models integrating forest structure compete better than those that do not [8,9]. Logistic regression proved to be a robust method for modelling susceptibility to superficial landslides. Nevertheless, regional and local peculiarities still prevent transferring models readily from one area to another.

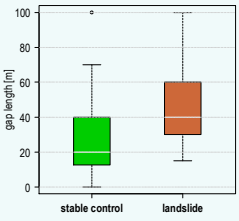

Fig. 5: Gap length in forest plots of St. Antönien (stable/unstable).

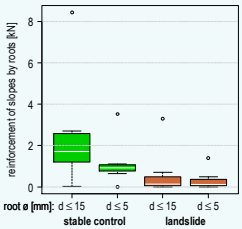

Fig. 6: Reinforcement of slopes by roots in forest plots (Fig. 5).

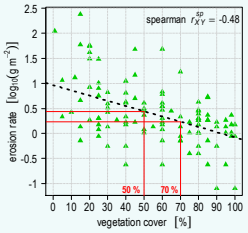

Fig. 7: Erosion related to cover of vegetation (50 / 70% threshold).

Gap length is a key variable (Fig. 5) indicating the importance of condition, management, and maintenance of forests. A correlation has been found between gap length and the potential of soil reinforcement by roots (Fig. 6). It was also found in the study area of St. Antönien that intensive grazing activities negatively affect slope stabilisation by roots [10].

Preliminary results on the influences of cattle grazing, vegetation cover, and interrill erosion support these findings (Fig. 7). Land-use management, therefore, should try to prevent damage to vegetation, resulting in a surface cover below 50% [11].

Module 3 (Implementation: concept for sustainable soil use and ecological restoration)

The Web-Interface for the WSL landslide database is one step to completion (Fig. 8) giving initially access to more than 600 datasets with comprehensive information for further analysis, model calibration and validation issues aiming at e.g. improving hazard maps.

A field survey was organised in the "Gangbach" area for discussing with the Advisory Board open questions related to biological slope stabilisation on-the-spot (Fig. 9). First recommendations and answers are compiled in the excursion guide [12] and in a synopsis on the practical work as well as the scientific basis and findings from the "Hexen- and Schwandrübi" investigation area [13]. Both records are serving as basis for the "guidelines for sustainable eco-engineering on steep slopes".

Additionally, the project has been subject of lectures at ETH, HAFL, ZHAW, of the EGU session "Eco-engineering", and of a workshop in Vienna (**EU project REVENUES**).

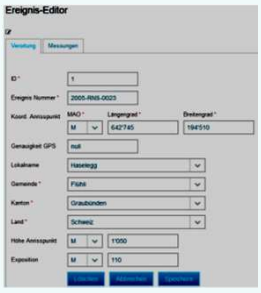

Fig. 8: Web-Interface of landslide database

Fig. 9: On-the-spot discussion during the "Gangbach" excursion.

Activities and milestones in Research① and Implementation②

① Root and mycorrhiza analysis → partly in co-operation with **M. van der Heijden *et al.*** (NRP 68)
① 2nd series (St. Antönien soil) of shear tests following new design (cf. problems)
① Soil aggregate stability, root, and mycorrhiza analysis with St. Antönien soil

② Presentation of Module 1 by Anil Yildiz at 12th Swiss Geoscience Meeting (22-11-2014, Fribourg)
② Advisory Board: – workshop spring 2015 → outline of guidelines based on current data
– meeting (public) spring 2016 → presentation of 1st version of guidelines
② Shared PFC3D workshop (**REVENUES**) summer 2015: root and soil aggregate stability modelling
② Congresses: EGU (spring 2015); ECSMGE (fall 2015); spring 2016 (?)
② Scientific articles on shear tests, roots and mycorrhiza, spatial modelling, and numerics (PFC3D)
② In clarification: Contribution to FAN meeting (fall 2016) and VIB meeting (spring 2015/2016)

- NRP 68 collaboration: Marcel van der Heijden *et al.*
- Related ongoing projects: EU project REVENUES

Problems, Difficulties

- **A change in experimental design** is needed for the up-coming large-scale shear tests with plants and mycorrhizae as they proved much more challenging than could be expected from pre-testing
- **No applicants** for joint Master's (**M. van der Heijden *et al.***) "Root and mycorrhiza development"
- **No applicants** for the survey of representatives from Private Sector and Administration (Module 3)
- **Exceeding of budget** for modifications of the shear apparatus …

References (contributions of project members related to SOSTANAH)
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* member of Advisory Board

SLF WSL ETH Amt für Wald Graubünden, Uffizi forestal dal Grischun, Ufficio forestale dei Grigioni FNSNF