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 $\Phi'$ of the soil in the slope by more than $-5^\circ$, (ii) more than 50-70% of natural vegetation cover within succession paths to the target association e.g. NaS for forests, (iii) particularly on steep terrain no gaps (in forests) longer than $-25$ m and, (iv) the results of re-estimation models (geo-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 soil compared to non-planted soil (Fig. 1). Analysis of the reinforcing effect of roots and mycorrhiza might help to explain the large variance [1]. Addional positive correlations were found between soil aggregate stability and models integrating forest structure compete better than those that do not [8,9]. Logistic regression

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 land beneath. 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. Antinien that intensive grazing activities negatively affect slope stabilisation by roots [10]. Preliminary results on the influences of cattle grazing, vegetation cover, and intercellular 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 6000 assets with comprehensive information for further analysis, model validation 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 aims for the completion of the project (2012) are summarised in the report on the practical work as well as the scientific basis and findings from the "Hexen- and Schwandritz" investigation area [13]. Both records are serving as basis for the guidelines for sustainable eco-engineering on steep slopes.

Activities and milestones in Research1 and Implementation2
① Root and mycorrhiza analysis ② in co-operation with M. van der Heijden et al. (NRP 68)
② 2nd series (St. Antinien soil) of shear tests following new design (cf. problems)
③ Soil aggregate stability, root, and mycorrhiza analysis with St. Antinien soil
④ Presentation of Module 1 by Ani Yildiz at 12th Swiss Geoscience Meeting (22-11-2014, Fribourg)
⑤ Advisory Board – workshop spring 2015 – outline of guidelines based on current data
⑥ field meeting (public) spring 2016 → presentation of 1st version of guidelines
⑦ Shared PFC® workshop (REVENUES) summer 2015; root and soil aggregate stability modelling
⑧ Congresses: EGU (spring 2015); EGSME (fall 2015); spring 2016 (7)
⑨ Scientific articles on shear tests, roots and mycorrhiza, soil modelling, and numerics (PFC®)
⑩ In clarification: Contribution to FAN meeting (fall 2016) and IB meeting (spring 2016/2017)

Problems, Difficulties
- A change in experimental design is needed for the up-coming large-scale shear tests with plants and mycorrhiza as they proved much more challenging than could be expected from pre-testing
- No applicants for the survey of representatives from Private Sector and Administration (Module 3)
- Exceeding of budget for modifications of the shear apparatus

References
[1] NRP 68: Soil stability and natural hazards - from knowledge to action

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.
Fig. 5: Gap length in forest plots of St. Antinien (stable/instable).
Fig. 6: Reinforcement of slopes by roots in forest plots (Fig. 5).
Fig. 7: Envisage related to cover of vegetation (50% 70% threshold).
Fig. 8: Web-interface of landslide database
Fig. 9: On-the-spot discussion during the "Gangbach" excavation.