The effects of combined vegetation on the stream bank stability—numerical analyses of benchmark cases for a catchment in south-eastern Norway

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Vegetation is used as a nature-based solution (NBS) to restore rivers and mitigate water triggered processes along stream banks, such as soil erosion or floods. Furthermore, roots are well-known to improve the overall stability of slopes through hydro-mechanical reinforcement within the rooted zone. Vegetation based solutions require selection of species which are most suitable for specific locations, aimed at restoring the natural state and function of river systems in support of biodiversity, flood management and landscape development. Selecting a combination of different species (trees, shrubs and grasses) along different zones of the riverbank (upper part, along the slope, at the toe of the slope) can improve the conditions for the river system regarding biodiversity and flood management. However, how the combination of different plant species can improve the stability of the stream bank needs to be further studied. Relevant factors are both related to the improved mechanical strength of the soil from the roots and the changed pore pressure conditions. This work presents a methodological approach for slope stability modelling including vegetation. We present the results obtained from a series of slope stability analyses carried out by using the proposed methodology, for different topographical conditions (slope inclination), and different plant combinations for species typically found along streams in south-eastern Norway.

In this study, two types of tree species were selected, respectively Norway Spruce (Picea Abies) and Downy birch (Betula pubescens). The Goat willow (Salix caprea) was selected as shrub while a common mixed-grass was chosen as grass. Vegetation features were obtained from the literature. The plant combinations considered were: i) only grass, ii) grass and shrubs, iii) only trees, and iv) trees, shrubs and grass. The commercial software GeoStudio (GEO-SLOPE International, Ltd.) was used. The module SEEP/W was used for the hydrological modelling and the calculation of pore-water pressure distribution while SLOPE/W was used for the slope stability modelling and calculation of the safety factor through the rotational failure model proposed by Bishop.

Although one of the main outcomes is that the purely mechanical contribution of vegetation to slope stability could not be decoupled from the hydrological reinforcement (as the most critical shear surface occurred outside the rooted zone), the combinations including trees (both only trees and trees, shrubs and grass) gave the highest mechanical improvement to the stability. To assess
the hydro-mechanical reinforcement played by the combined vegetation, two seasons of the year were analysed (spring and autumn) and it was found that the main reinforcement occurs in the spring season, due to the favourable weather (more days of drying and lower rainfall intensity), and for combinations including low height vegetation (i.e. grass and shrubs) because of their better aboveground vegetation features. In conclusion, a mixed combination of vegetation (trees, shrubs and grass) is the most suitable for reaching the highest hydro-mechanical reinforcement of streambanks, and in the meantime boosting the ecosystem biodiversity.