Hillslope processes, eco-engineering and protective forests

Christian Rickli¹ and Frank Graf²

¹ WSL Swiss Federal Institute for Forest, Snow and Landscape Research, CH-8903 Birmensdorf, Switzerland. christian.rickli@wsl.ch
² WSL Institute for Snow and Avalanche Research SLF, CH-7260 Davos Dorf, Switzerland. graf@slf.ch

Abstract
Rainfall events in mountain regions are frequently associated with numerous hillslope processes, which may threaten life and property. It is widely recognised that vegetation can considerably improve the stability of the slopes. The positive effects of plants are not only important in influencing and controlling hillslope processes, such as shallow landslides and erosion, but also in stabilising and revegetating landslide scars and artificial escarpments. Although there has been extensive research on the stabilising effects of plants on soil and slopes, still many questions remain about understanding these effects. The present issue of "Forest, Snow and Landscape Research" contains recent studies carried out at the Swiss Federal Institute WSL on the effects of vegetation and tree roots on slope stability, and on the long-term behaviour of different technical and biological measures used to stabilise slopes. It was found that among technical constructions gabions were fully functional after about 25 years but the timber of log crib walls had considerably deteriorated. On the other hand such accompanying biological measures as alder plantings were found to have resisted several heavy thunderstorms even though the actual slope gradient was about 5° steeper than the calculated allowable angle of internal friction. This increase in the angle of internal friction of about 5° was shown experimentally using triaxial compression tests.

The dimensions of landslides in forests were not found to be significantly different from those in open land. However, in forests, they occurred with lower densities and on steeper slopes, which may be important to consider when compiling hazard maps. Revegetation measures were found to increase soil aggregate stability by substantially accelerating vegetation development and promoting soil formation processes, such as the accumulation of fine soil particles, organic matter and mycorrhizal propagules. Measurements of root tensile strength indicate that the root system of protection forests loses most of its soil-stabilising function within 15 to 20 years of forest disturbances such as windthrow or bark beetle outbreak. It can be assumed that this period of time is not long enough for new tree generations to have grown enough to stabilise the soil effectually, particularly at high altitudes. Finally, another aspect exploited in this issue is the application of new technologies like laser-scanning to create a realistic three-dimensional model of a complex root system. This is an important step towards a better quantification of tree anchorage and stability. The contributions should be particularly relevant to foresters, eco-engineers and specialists involved in hazard mitigation.

Keywords: shallow landslides, erosion, protective forests, eco-engineering, slope stabilisation, soil aggregate stability, triaxial compression test, shear strength, root system architecture, root tensile strength
Foreword

Hillslope processes are recurrent phenomena on steep slopes. In Switzerland, for example, almost every year heavy rainfall events result in up to hundreds, sometimes even thousands of landslides and debris slides, which often cause huge damage to infrastructure and property and sometimes even loss of human life. Slope instability is thus a major concern for hazard mitigation. Consequently, reliable information on how to protect slopes against erosion and landslides, and how to stabilise those already affected is needed. In this connection, the importance of vegetation has been known for centuries and adequate measures have been practiced throughout the world. However, the exact contribution of the vegetation towards slope stability and the underlying mechanisms involved are still not fully understood. Moreover, sound methods to predict the stability of slopes covered with vegetation have yet to be developed. Consequently, these areas have been the subject of extensive research endeavours for decades at the Swiss Federal Institute WSL and elsewhere. Important research topics internationally include the consequences of intensive harvesting activities and deforestation on the occurrence of shallow landslides, and how to measure the root reinforcement of soil and incorporate this in slope stability rating models. Despite considerable research efforts, several questions remain only partly answered: 1) how much influence do specific vegetation-types have on reducing hillslope processes? 2) how can this vegetation be best managed to provide sustainable and the most effective protection against shallow landslides and erosion?, and 3) what is the long term efficiency of joint technical and biological measures?

The present issue "Hillslope processes, eco-engineering and protective forests" contains several contributions on vegetation and hillslope processes, such as shallow landslides and erosion, which have recently been investigated at WSL. BOLL et al. describe the long-term behaviour of selected technical and biological measures, such as wooden check dams and joint technical and biological measures in steep scree slopes, and discuss, among other issues, the interactions between the different measures. RICKLI and GRAF investigate the effects of forests on shallow landslides on the basis of detailed landslide inventories after different rainfall events. They focus on the question of the differences and similarities between forest and open land with respect to both the frequency and dimensions of the landslides and certain site parameters of the release zones. BURRI et al. propose a new approach to evaluate the effectiveness of eco-engineering measures. They compared a landslide area with a re-vegetated site and a control site with only technical stabilisation measures of the same age, as well as a climax forest site. They found that soil aggregate stability was an integral indicator of soil structure status and may therefore be applied in assessing the effectiveness of biological measures. GRAF et al. quantify the influence of plant roots on soil strength on the basis of triaxial shear tests, comparing both samples of pure soil and samples of planted soil. The results indicate that the vegetation effects can be expressed as an increase in the angle of internal friction of the soil. AMMANN et al. examine the development of root reinforcement after forest die-off, and found that the tensile strength of roots decreased markedly with increasing number of years after death. This means that the root system of a protection forest loses its soil-stabilising function some years after harvesting activity or after a natural disturbance such as windthrow or a bark beetle outbreak. Finally, GARTNER et al. describe a new method to analyse coarse tree root systems. The successful application of a laser scanner allows a 3D-model of exposed roots to be created, and, consequently, the root systems and their architecture to be analysed quantitatively.

The danger due to erosion and landslides caused by heavy rainfall will remain considerable in future. Higher rainfall intensities have to be expected as a consequence of climate change. On the other hand, forecasting landslides both temporally and spatially is still difficult. In our opinion, the importance of vegetation both to reduce hillslope processes and
concerning stabilisation measures will increase – not least because comprehensive technical measures for landslide prevention are very expensive and not always efficient. Therefore, the effect of vegetation on slope stabilisation and quantifying these effects will remain important research topics within the larger field of hazard mitigation.

We thank the numerous reviewers for their helpful comments, Silvia Dingwall for linguistically revising the manuscripts, Sandra Gurzeler for the layout and Ruth Landolt for her help editing this issue of "Forest Snow and Landscape Research".

Finally, we are particularly grateful to Albert Böll who initiated and established this field of research at WSL and who always has been a patient teacher and colleague to us.

July 2009
Christian Rickli and Frank Graf