QUANTIFYING ROOT REINFORCEMENT IN PROTECTION FORESTS: IMPLICATIONS FOR SLOPE STABILITY AND FOREST MANAGEMENT

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INTRODUCTION

The mechanical effect of roots on slope stabilization is widely recognized and is considered an important element in protection forests. However, the quantification of root reinforcement represents a challenge due to the complexity of root-soil frictional mechanisms and heterogeneous root distribution, as well as to the interaction of multiple factors such as soil type, moisture conditions, and wind solicitations. Many of these interactions are still not completely clarified yet, and new comprehensive approaches are in continuous development. Moreover, the transfer of knowledge from scientific platforms to practical applications has big limitations due to the amount of time and efforts needed to reduce detailed scientific methods and results to simple quantitative tools for the practice.
The objective of this work is to review the state of the art on approaches for the spatial characterization of root reinforcement, and to present a novel method for the implementation of quantitative approaches in the management of protection forests.

QUANTITATIVE APPROACHES FOR THE SPATIAL CHARACTERIZATION OF ROOT REINFORCEMENT

The mechanical contribution of roots to the stability of steep slopes is in most cases only qualitatively considered, and is based on approximative scientific studies. In particular, the results of scientific works of the last three decades are based on the approach of Wu (Wu et al., 1979), and on few datasets of tree root distributions in vertical soil profiles (without considering the horizontal variability).
The limitations of the Wu approach were listed in recent studies, empathizing the importance of the progressive nature of root bundles failure and the spatial heterogeneity of root reinforcement (reviewed in Schwarz et al. (2010)). These studies show that the Wu approach strongly overestimates root reinforcement (up to 300%, depending on the root distribution), and does not give information about the nature of root failures (stress-strain behaviors). Recent studies on root-soil interaction highlighted these aspects and proposed advanced quantitative approaches for the upscaling of root reinforcement from single root to stand scale, implementing new parameters that allow a better understanding of the root reinforcement mechanisms during the triggering of shallow landslides. The main innovative aspects of the new approaches reviewed in this work include: a) quantification of root spatial distribution and architecture (diameter and length), b) three-dimensional calculation of slope stability considering the lateral contribution of root reinforcement, and c) introduction of a strain-dependent quantification of root reinforcement under tension and compression zones.
The results of the above listed new approaches build up the basis for the understanding of the stabilizing mechanisms of root networks in vegetated slopes, thus allowing a better quantitative analysis of the most important factors related to forest management (such as forest structure and species composition).

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A NOVEL METHOD FOR THE MANAGEMENT OF PROTECTION FORESTS IN STEEP HILLSLOPES PRONE TO SHALLOW LANDSLIDES

In this study we present a novel method for the implementation of recent consolidated research findings in practical tools for the management of protection forest. In particular, we show how detailed data on root distribution and root mechanics can be upscaled to stand scale, and how these data can be used to characterize the spatial distribution of root reinforcement in a forest stand. These calculations of root reinforcement, combined with other simple stand characteristics (such as soil type, geology, and slope angle), are condensed in simple tables for a quantitative estimation of root reinforcement and slope stability in the field. This method is used to define a specific "minimal profile" of forest stands in the contest of a sustainable management concept for protection forests (Thormann and Schwitter, 2004).

In the first phase of the study the models for the quantification of root reinforcement are calibrated and validated with field data. Secondly, the calibrated models are used to calculate the values reported in the tables for field application. Finally, the novel method is applied for the planning of silvicultural interventions in forests with protective functions in the canton Bern (Switzerland). Practitioners are asked to use the method in the chosen study area, and the application of the method is replicated for each practitioner in each study area allowing for cross comparison and evaluation.

The results show the applicability of the novel method, and highlight the advantages of the novel method compared to the actual Swiss Guidelines for silvicultural interventions in protection forests (Frehner et al., 2005). The selected study areas are the objects of a planned monitoring program for the evaluation of the silvicultural measure effectivity in the long term.

FINAL REMARKS

In conclusion, we show that it is possible to define a minimal profile of protection forests in a quantitative and specific way, using consolidated research results condensed in "user friendly" tables that can be quickly consulted in the field. This method represents a considerable advance of the tools for the management of protection forests such as the Swiss Guidelines (Frehner et al., 2005), and show how detailed research results may be transferred to practical applications.

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