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Meta-analysis of the effects of plant roots in controlling concentrated flow erosion rates

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Vegetation is often used in ecological restoration programs to control various soil erosion processes. During the last two decades several studies reported on the effects of plant roots in controlling concentrated flow erosion rates. However a global analysis of the now available data on root effects is still lacking. Yet, a meta-data analysis will contribute to a better understanding of the soil-root interactions as our capability to assess the effectiveness of roots in reducing soil erosion rates due to concentrated flow in different environments remains difficult. The objectives of this study are therefore i) to provide a state of the art on studies quantifying the effectiveness of roots in reducing soil erosion rates due to concentrated flow; and ii) to explore the overall trends in erosion reduction as a function of the root (length) density, root system architecture and soil texture, based on a global analysis of published research data. We therefore compiled a dataset of measured relative soil detachment rates (RSD) for the root density (RD; 822 observations) as well as the root length density (RLD; 274 observations). Non-linear regression analyses showed that decreases in RSD as a function of RD and RLD could be best described with the Hill curve model. However, a large proportion of the variability in RSD could not be attributed to RD or RLD, resulting in a relatively low predictive accuracy of the Hill curve model with model efficiencies of 0.11 and 0.17 for RD and RLD respectively. Considering root architecture and soil texture yielded a better predictive model especially for RLD with ME of 0.37 for fibrous roots in a non-sandy soil. The unexplained variance is to a large extent attributable to measuring errors and differences in experimental set ups that could not be explicitly accounted for (e.g. tested plant species, soil and flow characteristics). However, using a Monte Carlo simulation approach, we were able to establish relationships that allow assessing the likely erosion-reducing effects of plant roots, while taking these uncertainties into account. Our analyses further showed that compared to RD, RLD is a much more suitable variable to estimate RSD, because it is indirectly correlated to root system architecture.