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The contribution of riparian vegetation to the stability of agricultural channels banks in the Lombardy plane

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Vegetation is well-known to affect the stability of slopes and banks in several ways, influencing both the water content and the mechanical properties of the soil. From the mechanical point of view, in particular, vegetation acts by means of the root system, which reinforces the soil. Three reinforcement mechanisms are generally recognised to prevent mass movements: the first is due to soil-roots interaction, which allows the mobilisation of the root tensile strength and increases the compound matrix (soil-fibre) strength, the second is due to great size roots intersecting the shear surface, which act as individual anchors, the third is due to the whole root system which exerts buttressing and arching actions. All these effects can be quantified via modelling if appropriate parameters are provided. Due to the scarcity of data, however, only the fibre reinforcement mechanism is generally considered and it is quantified in terms of additional root cohesion, which can be easily incorporated into stability models.

Root cohesion values can be estimated by means of direct shear tests (in situ or in laboratory), by means of back analysis of collapsed slopes and by means of modelling. Direct shear tests and back analysis, however, due to site-specific development of root systems (which leads to a dramatic space variability of root density and size), provide results that are valid only for the specific (or highly similar) conditions that occur in the location where the investigations are carried out. Reinforcement modelling, on the contrary, represents a more general way of estimating root cohesion along the soil profile. The scheme commonly adopted in modelling is the Wu (1976) and Waldron (1977) approach (W&W model), which estimates root cohesion values basing on root tensile strength and root density (in terms of Root Area Ratio). Despite its simplicity and some questions about the hypotheses involved in, it still represents the benchmark. To overcome some of such limitations, we have modified the model to account for the distribution of root cohesion (c_R) within the soil and the non-simultaneous root breaking:

$$c_R = k'k'' \sum_{i=1}^{N} (T_r a_r)_i$$

where T_r is the tensile strength and a_r is the Root Area Ratio (RAR) for roots belonging to diameter class i, N is the number of classes considered, k' is the factor accounting for the decomposition of root tensile strength and k'' is a factor accounting for the non-simultaneous breaking of roots.

In the present work the modified W&W model has been adopted to estimate the root cohesion due to the riparian vegetation, and the bank stability, for six study sites belonging to two small agricultural channel of the Lombardy plane.

The study sites consist of very steep banks (45-50°) with the following riparian vegetation, typical of the considered landscape: *Sambucus nigra*, *Acer campestre*, *Rubus* spp., *Populus Canadensis*.

Several samples of roots have been taken at each site, in order to carry out laboratory tensile strength tests and to develop the strength-diameter relationships, which are requested to estimate the tensile strength of the roots of the different size according to their species.

Trenches have been excavated into the bank at each site in order to identify all the roots of different size present at each depth, and to estimate RAR distribution with depth.

Estimated root cohesion values for each site have been then used into a bank stability model to evaluate the current Factor of Safety values, that have been compared with those resulting from banks without vegetation.

Results show that in the selected cases, riparian vegetation is crucial in determining the stability of the banks. Neglecting the estimated values of cohesion, in fact, banks result extremely unstable, according to their soil properties and their steepness.