Biotechnical engineering on alluvial riverbanks of southeastern Australia:

A quantified model of the earth-reinforcing properties of some native riparian trees

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Abstract

It is generally accepted that tree roots can reinforce soil and improve the stability of vegetated slopes. Tree root reinforcement is also recognised in riverbanks although the contribution that the roots make to bank stability has rarely been assessed due to the reluctance of geomorphologists to examine riverbank stability by geomechanical methods that allow for the inclusion of quantified biotechnical parameters. This study investigates the interaction between alluvial soil and the roots of four southeastern Australian riparian trees. It quantifies the amount and distribution of root reinforcement present beneath typically vegetated riverbanks of the upper Nepean River, New south Wales, and examines the effect of the reinforcement on the stability of these banks.

The ability of a tree to reinforce the soil is limited by the spatial distribution of its root system and the strength that the roots impart to the soil during shear. These two parameters were determined for the following four species of native riparian tree: *Casuarina glauca*, *Eucalyptus amplifolia*, *Eucalyptus elata*, and *Acacia floribunda*. The four species all exhibit a progressive reduction in the quantity of root material both with increasing depth and with increasing lateral distance from the tree stem. In the vertical direction there are two distinct zones that can be described. The first occurs from between 0 and approximately 15 % of the maximum vertical depth and consists of approximately 80 % of the total root material quantity. In this zone the root system consists of both vertical and lateral roots, the size and density of which varies between species. The second zone occurs below approximately 15 % of the maximum vertical depth and consists primarily of vertical roots. The quantity of root material in this zone decreases exponentially with depth due to the taper of individual roots.

The earth reinforcement potential in terms of both geometric extent and the quantity of root material expressed as the Root Area Ratio (RAR) varies significantly from species to species. *E. elata* exhibited the highest values of RAR in soil zones beneath it while *E. amplifolia* reinforced a greater volume of soil than any of the other species examined.

The increased shear resistance (S_r) of alluvial soil containing roots was measured by direct in-situ shear tests on soil blocks beneath a plantation. For three of the species (*C. glauca*, *E. amplifolia*, *E. elata*) S_r increased with increasing RAR measured at the shear plane, in a similar linear relationship. The shear resistance provided by *A. floribunda* roots also increased with increasing RAR at the shear plane but at a much greater rate than for the other three species. This is attributable to *A. floribunda*'s greater root tensile strength and therefore pull-out resistance, as well as its smaller root diameters at comparative RARs which resulted in a greater proportion of roots reaching full tensile strength within the confines of the test.

Tree roots fail progressively in this system. Therefore determining the increased shear strength from the sum of the pull-out or tensile strengths of all individual roots and Waldon's (1977) and Wu's (1979) simple root model, would result in substantial over estimates of the overall strength of the soil-root system. The average difference between S_r calculated in this manner and that measured

from direct in-situ shear tests is 10.9 kPa for *C. glauca*, 19.0 kPa for *E. amplifolia*, 19.3 kPa for *E. elata*, and 8.8 kPa for *A. floribunda*.

A riverbank stability analysis incorporating the root reinforcement effect was conducted using a predictive model of the spatial distribution of root reinforcement beneath riparian trees within the study area. The model is based on measurements of juveniles and observations of the rooting habits of mature trees. It indicates that while the presence of vegetation on riverbank profiles has the potential to increase stability by up to 105 %, the relative increase depends heavily on the actual vegetation type, density, and location on the bank profile. Of the species examined in this study the greatest potential for improved riverbank stability is provided by *E. amplifolia*, followed by *E. elata*, *A. floribunda*, and *C. glauca*.

The presence of trees on banks of the Nepean River has the potential to raise the critical factor of safety (FoS) from a value that is very unstable (0.85) to significantly above 1.00 even when the banks are completely saturated and subject to rapid draw-down. It is likely then that the period of intense bank instability observed within this environment between 1947 and 1992 would not have taken place had the riparian vegetation not been cleared prior to the onset of wetter climatic conditions. Typical 'present-day' profiles are critically to marginally stable. The introduction of vegetation could improve stability by raising the FoS up to 1.68 however the selection of revegetation species is crucial. With the placement of a large growing Eucalypt at a suitable spacing (around 3-5 m) the choice of smaller understorey trees and shrubs is less important.

The effect of riparian vegetation on bank stability has important implications for channel morphological change. This study quantifies the mechanical earth reinforcing effect of some native riparian trees, thus allowing for improved deterministic assessment of historical channel change and an improved basis for future riverine management.

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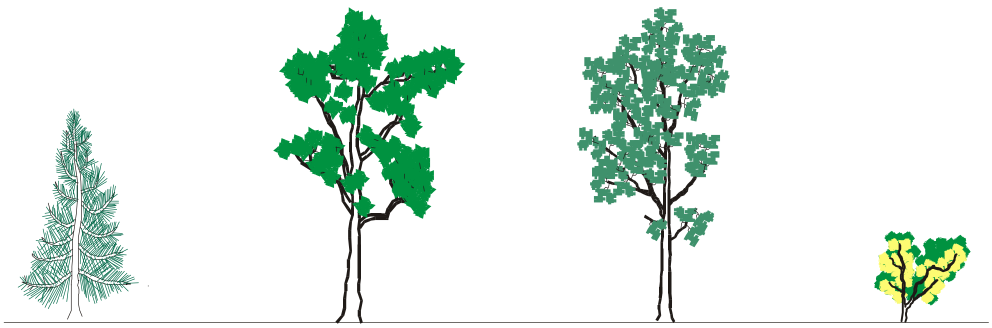
Sample numbering

The numbering of samples involved characters that represent the soil or species being tested, the test type, and the number of the sample.

S :	Soil	A :	Architectural
CG :	*Casuarina glauca*	ST :	Shear tests
EA :	*Eucalyptus amplifolia*	PT :	Pull-out test
EE :	*Eucalyptus elata*	TT :	Tension Test
AF :	*Acacia floribunda*		

e.g. AFA3 is *Acacia floribunda* Architectural sample number 3.

Illustration Key



Casuarina glauca *Eucalyptus amplifolia* *Eucalyptus elata* *Acacia floribunda*

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