Mechanical Properties of Native Tree Species for Soil Bioengineering in Northeastern Mexico

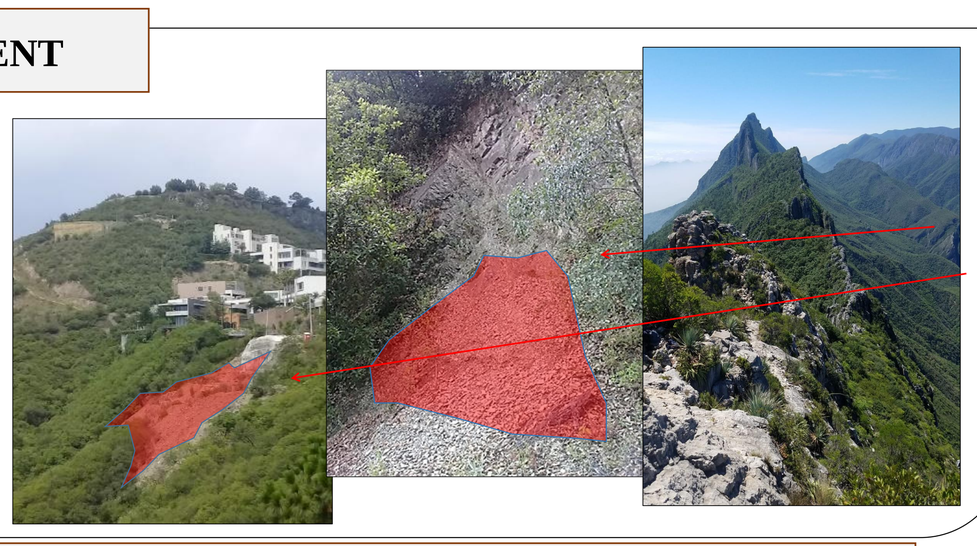
Zavala-González R[1]., Cantu-Silva I[1]., González-Rodríguez H[1]., Tetsuya Kubota[2]

[1] Autonomous University of Nuevo Leon, Faculty of Forest Sciences, Carretera Nacional No. 85, Km 145, Linares, Nuevo León, México 67700; [2] Faculty of Agriculture, Kyushu University, Fukuoka Japan.

1-INTRODUCTION/PROBLEM STATEMENT

- Due to causes such as small-scale earthquakes or the increasing amount of heavy rainfall extreme events, many slopes are potentially unstable.
- This plays an important role on the slopes of this orogenic belt, making areas like the one in this study prone to landslide disasters.

Soil bioengineering is an effective tool for treatment of a variety of unstable and/ or eroding sites.



2- RESEARCH QUESTIONS AND HYPOTHESIS

1.-Maximum force to breakage of roots is influenced by diameter?

Tensile strength and modulus of elasticity of roots is different between four species:*Cercis canadensis*, *Celtis laevigata*, *Quercus rysophylla* and *Ligustrum lucidum*.

3.- EXPERIMENTAL SETUP

Sampling method

The species considered were selected based on their **native characteristics** and widespread existence on the **slopes**.

Preparation of root samples for analysis

The roots were extracted from exposed root systems with least disturbance in the area. and the root samples were classified by diameter range and They were cut to approximately 10 cm in length and individually labeled for further testing.

Tensile strength test

Regarding tree forest species, the tests were conducted with the Universal Testing Machine Shimadzu type SLFL-100KN.

$T_s = F_{max} / \pi (D/2)^2$

$E_{root} = (F_{max}/A_0)\ CE/L_0$

Mattia et al., 2005, Genet et al. 2005, Bischetti et al., 2005, De Baets et al., 2008

Statistical analysis

Data was analyzed using the Statistical Program for Social Sciences (SPSS) standard version 13.0 for Windows

(SPSS Inc., Chicago, IL.)

Kruskal-Wallis test.
Mann-Whitney U.

(Steel and Torrie, 1980)

4.-RESULTS

A total of 120 samples were successfully tested: 30 for each species

Tension tests were conducted successfully on 85% of the total collected samples.
The remaining 15% failed by root system damage instead of the applied tension, that is attributed to tests discarded by displaced bark

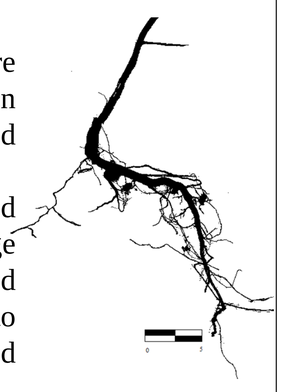


Table 1. P values of the Mann Whitney U test to compare root diameter, tensile strength (T_s) and modulus of elasticity (E_{root}) in different species

	vs	Diameter	T_s	E_{root}
C. canadensis	*C. laevigata*	0.41	0.14	**0.04**
	Q. rysophylla	0.60	**0.01**	**0.00**
	L. lucidum	0.21	0.59	0.25
C. laevigata	*Q. rysophylla*	0.32	0.45	0.3
	L. lucidum	0.50	**0.00**	0.80
Q. rysophylla	*L. lucidum*	0.24	0.14	**0.00**

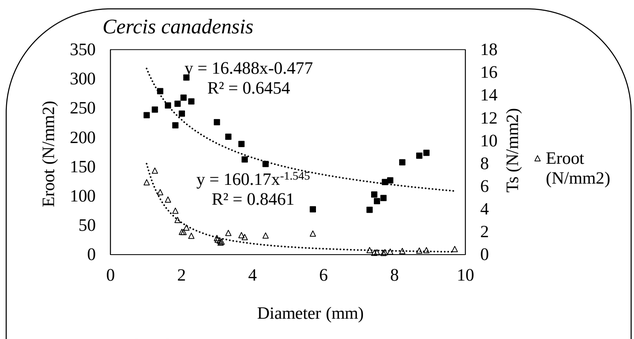
If p values are ≤0.05, the mean comparison is declared different.

The relationships among root diameter, tensile strength (T_s), and modulus of elasticity (E_{root}) was negative and could be fitted with a power regression equation, showing highly significant values $p<0.01$.
Celtis laevigata showed the maximum value of tensile strength (T_s) 28.11 N/mm^2 while the minimum value of tensile strength was observed in *Ligustrum lucidum* 5.27 N/mm^2.
For the variable modulus of elasticity (E_{root}) C*eltis laevigata* showed the maximum value of 90.01N/mm^2 while the minimum value of modulus of elasticity was observed in *Ligustrum lucidum* 29.16 N/mm^2.

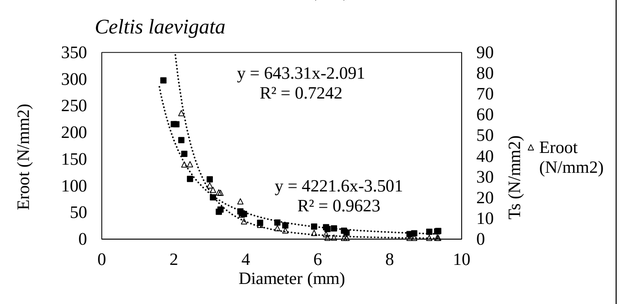
Table 2. Maximum, minimum and average values of maximum force to root breakage (F_{max}), tensile strength (T_s) and modulus of elasticity (E_{root}) of the ten species analyzed.

	F max (N)			T_s (N/mm^2)			E_{root}(N/mm^2)		
Species	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Cercis canadensis	815.63	12.50	161.56	12.25	4.73	9.09	143.31	35.94	52.32
Celtis laevigata	500.28	60.25	150.32	47.77	6.50	28.11	236.34	11.69	90.01
Quercus rysophylla	550.00	18.75	143.43	32.91	7.60	16.75	98.20	6.37	32.47
Ligustrum lucidum	646.88	15.50	157.79	16.02	4.92	5.27	50.14	12.93	29.16

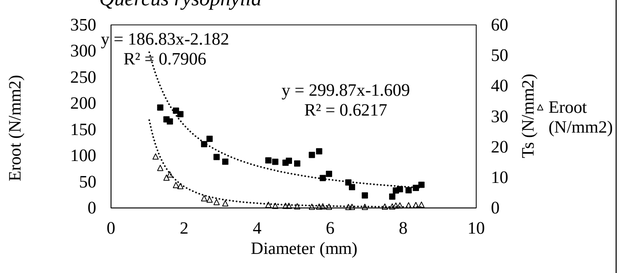
Cercis canadensis



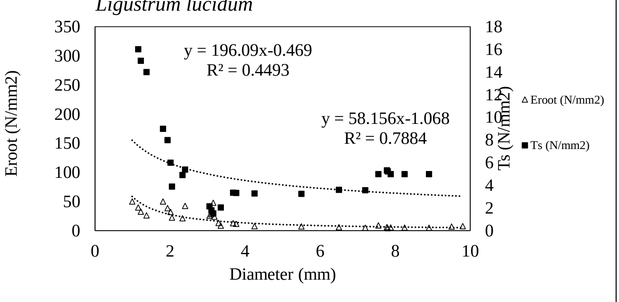
Celtis laevigata



Quercus rysophylla



Ligustrum lucidum



elationship between diameter of roots, tensile strength (T_s) and Modulus of elasticity (E_{root})

5.-CONCLUSIONS

Results of mechanical proprieties are showed the following ascending order: *Ligustrum lucidum* < *Quercus rysophylla* < *Cercis canadensis* < *Celtis laevigata*.
Likewise, *Celtis laevigata* showed the highest tensile strength and modulus of elasticity of all investigated species.

Bibliography

Bischetti, G.B., Chiaradia, E.A., Epis, T., Morloti, E., 2009. Root cohesion of forest Species in the Italian Alps. *Plant Soil*, 71-89. DOI: 10.1007/511104-009-9941-0
De Baets S, Poesen J, Reubens B, Wemans K, De Baerdemeaker J, Muys B. 2008. Root tensile strength and root distribution of typical Mediterranean plant species and their contribution to soil shear strength. *Plant Soil* **305:**207–226. DOI: 10.1007/511104-008-9553-0
Gray DH. Sotir RB. 1996. Biotechnical and Soil Bioengineering Slope Stabilization: A Practical Guide for Erosion Control. 35-37. New York: John Wiley & Sons.
Improvement **4**:81–89.DOI:10.1680/grim.2000.4.2.81
Pollen N. 2007. Temporal and spatial variability in root reinforcement of steambanks: accounting for soil shear strength and moisture. *Catena* **69:**197-205. DOI:10.1016/j.catena.2006.05.004
Pollen N, Simon A. 2005. Estimating the mechanical effects of riparian vegetation on steam bank stability using a fiber bundle model. *Water Resources Research* **41:**1-11. DOI: 10.1029/2004WR003801