H31B-02

Geomorphic Effect of Wood in Southern Andes Streams: Evidences From Three Mountain Basins

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AGU Joint Assembly
Acapulco, Mexico – 22-25 May, 2007

1. Introduction

Most of the geomorphological research on LWD has been carried out in the Pacific Northwest region of North America, followed by increasing investigations in Europe, with few papers on the subject published about other continents. Among the different parts of the world, the humid – temperate and cold – regions of the South American continent are characterized by thousands of streams flowing through old-growth forests, where LWD can be expected to affect significantly stream morphology. However, no investigations have been published so far on such regions.

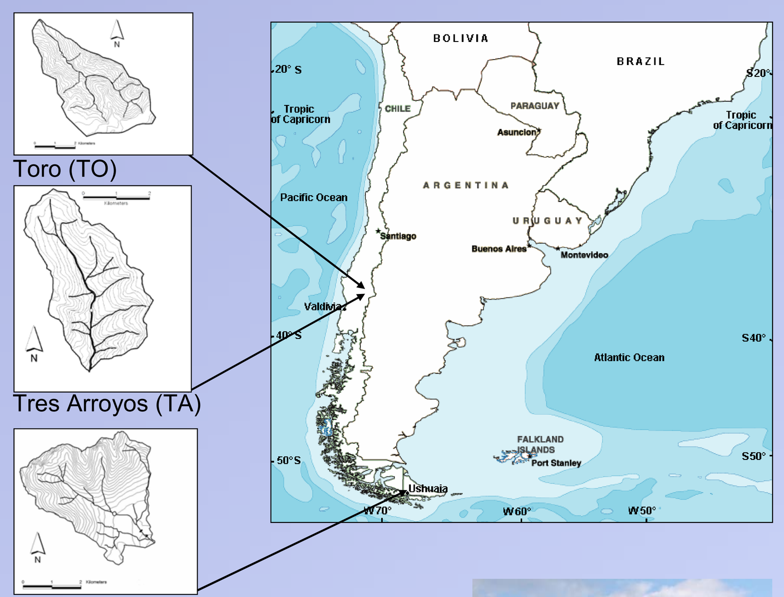
Native forests are becoming progressively less abundant in the Southern Andes and neighboring piedmont areas (within the territories of Chile and Argentina) due to deforestation for agricultural production and for the more profitable industrial plantations of fast-growing species, mostly Eucalyptus spp., Douglas fir (*Pseudotsuga menziesii*) and Monterey Pine (*Pinus radiata*). In particular, the Chilean native temperate rainforest – the so-called Valdivian forest, very similar to the Pacific Northwest forests along the Coastal Range – has been largely eliminated in the piedmont valleys of central and southern Chile.

However, portions of native old-growth forest – dominated by southern beeches (*Nothofagus spp.*) and, locally, araucaria (*Araucaria araucana*) – are still present within National Parks and Reserves. These locations thereby provide excellent investigation areas for analyzing the influence of large woody debris on the morphology and dynamics of mountain rivers in quasi-pristine environments. In contrast, in the Tierra del Fuego the vast majority of river basins (98%) are heavily impacted by the damming activity of beavers (*Castor canadensis*), after their artificial introduction in the 1946.

The purpose of this study is to provide the first quantitative description of abundance and morphological role of in-channel wood in mountain streams of the Southern Andes. The research lies in the framework of the European Union Project "*Epic Force*" (Evidence-based policy for integrated control of forested river catchments in extreme rainfall and snowmelt, www.tesaf.unipd.it/epicforce) coordinated by Prof. J. Bathurst (University of Newcastle, UK). Support was provided by Universidad Austral de Chile (located in Valdivia) for field activities in the Chilean Andes, and by the Subsecretaría de Recursos Hídricos de Tierra del Fuego (located in Ushuaia) and Universidad Nacional de La Plata for the field surveys in Tierra del Fuego (Argentina).

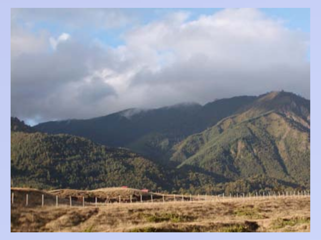
2. Study sites

The investigated sites are three basins mostly covered by Nothofagus forests: two of them are located in the Southern Chilean Andes (the Tres Arroyos and the Río Toro) whereas one basin lies in the Argentinean Tierra del Fuego (the Buena Esperanza, one of the few channels not impacted by beavers). The Tres Arroyos and Buena Esperanza are gauged for water discharge since 1998 and 1999, respectively.



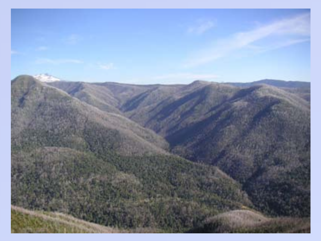
Basin characteristics	Tres Arroyos (TA)	Toro (TO)	Buena Esperanza (BE)
Basin Area (km²)	9.1	11.1	12.9
Channel order	3	3	3
Climate	Temperate humid	Temperate humid	Subantartic (Cold humid)
Geology (rock type)	Volcanic / pyroclastic	Volcanic / pyroclastic	Sedimentary
Forest cover (%)	74	98	34
Dominant forest species	*Nothofagus dombeyi* *Araucaria araucana*	*Nothofagus dombeyi* *Araucaria araucana*	*Nothofagus pumilio* *Nothofagus antartcica*
Forest disturbances	Wildfire (1920's) Debris flows in tributaries	Wildfire (2002)	Roads,skitrails (late XXcentury) of minor relevance
Total channel length (km)	4.9	7	7.5
Studied channel length (km)	1.54	2.17	1.85
Average channel slope (m/m)	0.08	0.05	0.065
Average channel width (m)	7.7	11.9	6.3

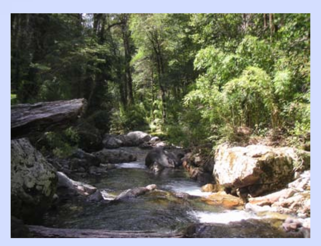
Tres Arroyos

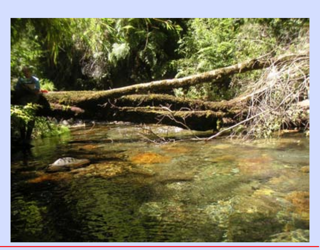




Toro

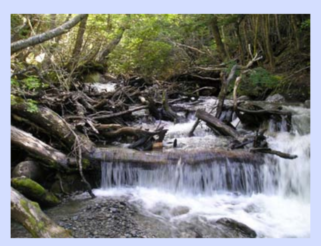


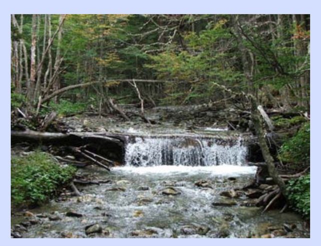




Buena Esperanza



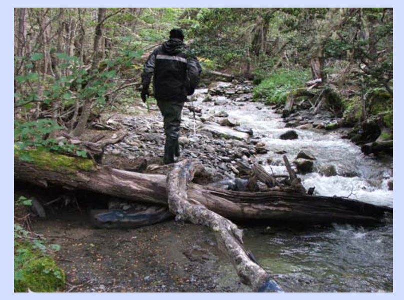
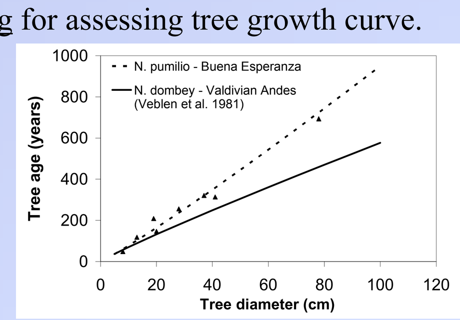


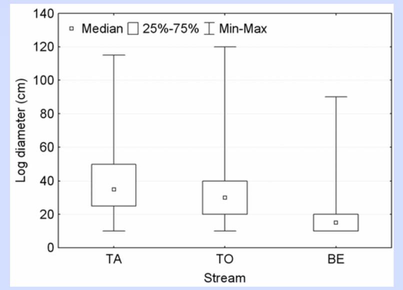


3. Field activities

Field work took place in March-April 2005 and December-March 2006.The following activities were carried out:

- Subdivision of each stream into different reaches based on morphological and wood homogeneity;
- Survey of longitudinal profile and cross-sections;
- Measurements and characterization of LWD pieces (diameter >10 cm, length > 1 m) both in the active channel and in the floodplain, for a total >5,500;
- Annotation of additional information relative to each LWD piece: type, orientation to flow, input mechanism (fluvial transport, bank erosion, landslide, natural mortality) and position with respect to flow;
- Measurements of wood jam dimensions and type following Abbe and Montgomery's (2003) classification;
- Measurements of sediment volume stored behind log-step and valley jams;
- Evaluation of flow velocity and flow resistance in selected sub-reaches of Tres Arroyos (TA) and Buena Esperanza (BE) through the salt tracer methodology;
- Installation of metal tags into 322/481 wood pieces in the TA (2005) and BA (2006), respectively;
- Survey of log displacement in the TA (2006), after spring runoff (peak discharge 4.2 m^3s^{-1}, around bankfull stage);
- Tree coring for assessing tree growth curve.

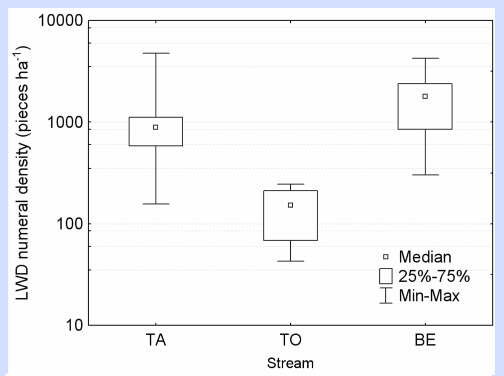




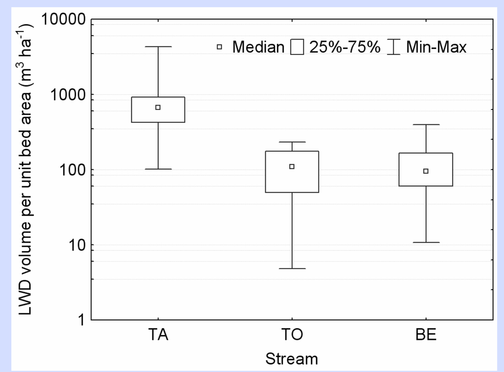


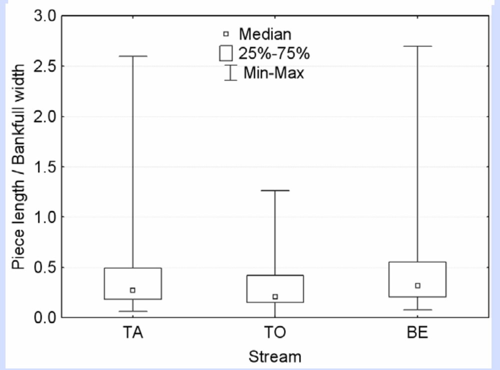


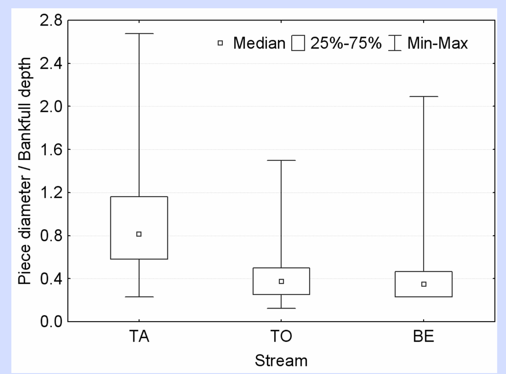
4. Analysis of results

LWD number, volume and dimensions (within bankfull channels)





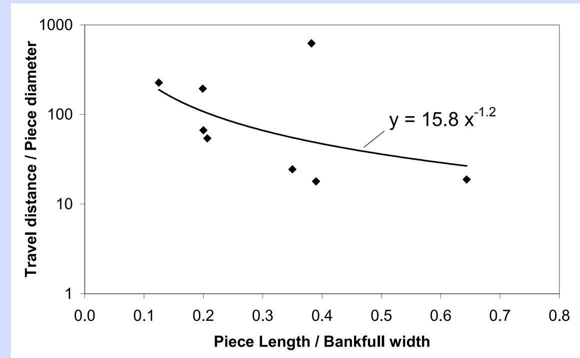




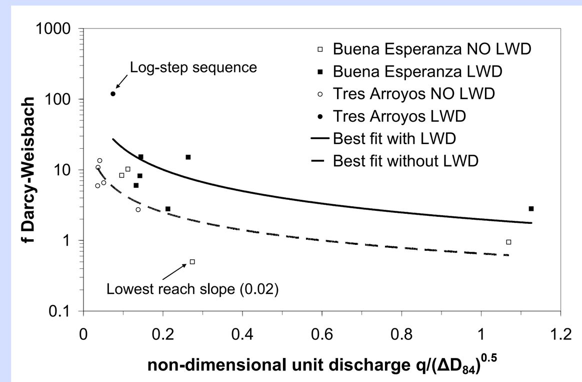
Input mechanisms Logs showing transport signs are 68% (TO), 74% (BE) and 88% (TA). However, in the TA, many transported pieces come from debris flows. Of the remaining pieces, natural mortality is the main source (10% TA, 12% BE, 27% TO). Bank erosion inputs in the BE are high (11%), whereas low (0-1%) for the others. Landslide inputs are generally low (<5%).

Log mobility (Tres Arroyos only)

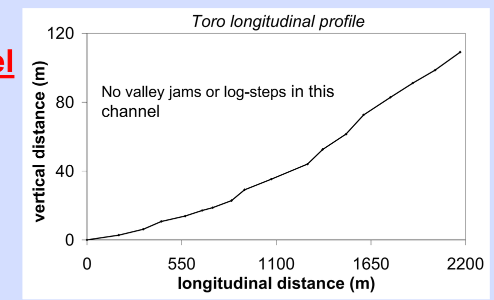
8 (+7 not recovered) pieces were moved by a bankfull event, i.e. about 4% of the tagged.

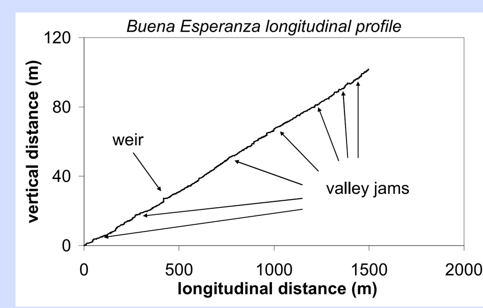


Hydraulics effects of LWD



Effects on channel morphology and sediment storage





Total elevation drop due to LWD:

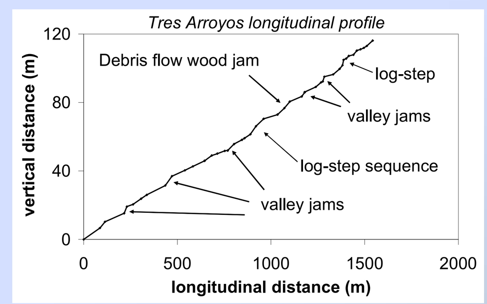
- *TO* ⇨ *0 %*
- *BE* ⇨ *24 %*
- *TA* ⇨ *27 %*

Sediment stored by LWD structures:

- *TO* ⇨ *0 m^3km^{-1}*
- *BE* ⇨ *872 m^3km^{-1}*
- *TA* ⇨ *1,270 m^3km^{-1}*

⇩

150% of the annual sediment yield of the TA



5. Conclusions

- Old-growth forested basins in the Southern Andes feature large quantities of wood, which may exert a strong control on fluvial processes;
- A marked latitudinal difference in LWD diameters is present, likely for the slower tree growth in the cold climate of the Tierra del Fuego;
- Major differences in LWD abundance and volumes exist even between "adjacent" basins, due to the basins' disturbance history (fire);
- The Fueginan basin features a larger number of wood pieces, possibly because thinner elements are easier to break up during floods;
- Massive LWD volumes (i.e. > 1,000 m^3ha^{-1}) can be reached in basins disturbed by fires followed by mass movements and debris flows;
- Wood mobility at bankfull conditions appears quite scarce, with travel distances inversely related to the piece length/channel width ratio;
- The presence of log-steps and large jams increase flow resistance up to one order of magnitude;
- Potential energy dissipation due to LWD (log-steps and valley jams) is about ¼ of the total elevation drop in wood-rich streams;
- Sediment stored behind log-steps and valley jams is around 1,000 m^3km^{-1}, which may be of the same order of the annual sediment yield;

Acknowledgements: This research was funded by the EU Project INCO-CT-2004-510735 **EPIC FORCE** (*Evidence-based policy for integrated control of forested river catchments in extreme rainfall and snowmelt*), coordinated by Prof. James Bathurst (University of Newcastle upon Tyne, UK). The consortium are composed by Università degli Studi di Padova (Italy), Universidad Politecnica de Madrid (Spain), Universidad Nacional de Costa Rica (Costa Rica), Universidad de Cuenca (Ecuador), Universidad Austral de Chile (Chile), Universidad Nacional de La Plata (Argentina) and Subsecretaría de Recursos Naturales de Tierra del Fuego (Argentina). We would like to tanks Sarah Burns, Pablo Velásquez, Lorenzo Picco, Giovanni Carlig, Paula Uyttendaele.