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EPIC FORCE

Evidence-based Policy for Integrated Control of Forested River Catchments in Extreme Rainfall and Snowmelt

Instrument: Specific Targeted Research Project

Thematic Priority: Specific Measures in Support of International Cooperation, Developing Countries, A.2 Rational Use of Natural resources, A.2.1 Managing humid and semi-humid ecosystems

Deliverable D12

Large Woody Debris Field Data and Methodology: Chilean Basins

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Introduction

The investigated sites were two basins in the Southern Chilean Andes (Tres Arroyos in the Malalcahuello National Reserve and Rio Toro within the Malleco Natural Reserve, Fig. 1). Personnel from UNIPD included Mr Andreoli (PhD student), Dr. Comiti (Post-doc), Mr Carling and Mr. Picco (undergraduate students), who tightly collaborated with the personnel of UACH (Partner 6, in particular Ms Uyttendaele, Mr Opazo Urrutia and Prof. Iroumè). The field work was carried out here during March-April 2005 and November 2005-January 2006. The activities included: LWD survey, LWD tagging with metal tags, channel topographic survey (longitudinal and cross-sections), bed grain size analysis, morphological description, measurements of flow discharge and mean velocity through the salt dilution and salt tracer methodology.

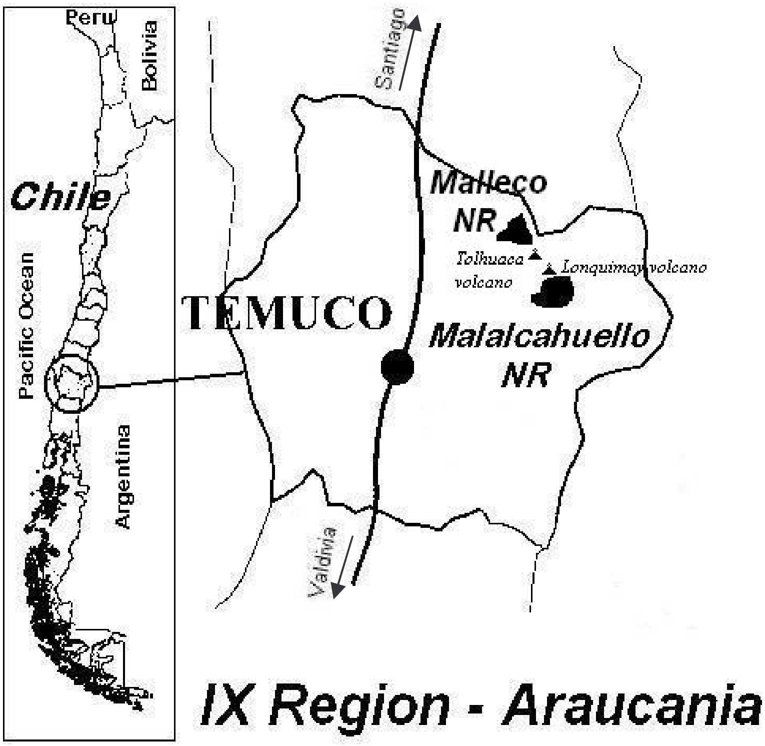


Figure 1 – Location map of the two study basins: the Tres Arroyos lies in the Malalcahuello National Reserve and the Rio Toro is within the Malleco Natural Reserve.

Methodology

Based on the preliminary field experience in Italian basins (Comiti et al., 2006; Mao et al., 2006), the following methodologies were applied and transferred from UNIPD to UACH:

Survey of channel topography, morphology and grain size

The topographic survey of channel longitudinal profiles and cross-sections was performed by a laser distance meter with inclinometer, coupled to a prisma rod. Reaches were defined based on uniformity of either slope, channel width or abundance of woody debris. The end sections of each reach were fixed by wood stakes on channel banks. Bankfull width and depth, and floodplain width, were measured for each reach. Additionally, for each reach the number of boulders and steps (larger than bankfull depth) was noted. Bed surface grain size was measured by using the grid-by-number method, measuring clasts by calibers (tree caliber for coarse particles).

The Montgomery and Buffington (1997) classification was adopted to define reach-scale bed morphology. The vegetation adjacent to each reach was described (average size, type, stability and disturbances)

Assessment of LWD volume, dimensions and characteristics

Measured LWD was all wood pieces > 10 cm in diameter and > 1 m in length both in the active channel and in the adjacent active floodplain. Of each piece, its length and its mid-diameter were measured by a tape meter and a tree caliber, respectively. Pieces forming log jams (i.e. accumulations of ≥ 2 elements) were all measured and the geometrical dimensions of jams (length, width and height) were taken. Jam type was defined based on Abbe and Montgomery (2003) classification.

Additional information relative to each LWD piece were recorded during the field survey: type (log, rootwad, log with rootwads attached), orientation to flow, origin (floated, bank erosion, landslide, natural mortaility, harvest residuals) and position (log-step, in-channel, channel-bridging, channel margins, bankfull edge).

Assessment of LWD influence on channel sediment storage

Sediment stored behind log-steps and valley jams was evaluated approximating the sediment accumulated to a solid wedge (porosity is not taken into account) whose geometrical dimensions (i.e. streamwise length, upstream and downstream width, depth) were measured by a tape.

Evaluation of LWD mobility

500 metal tags were inserted into 322 wood elements (1-3 tags per log) of different size and location, in order to track their movements over time using wood stakes at reach end sections as reference points, and measuring the distance of the centre of each log from the reference point by a laser distance meter. Re-survey of all tagged logs was carried out in the Tres Arroyos in December 2005, after spring runoff. Future re-survey should be done after each possible log-moving flood events.

Measurements of flow discharge, velocity and resistance

Flow discharge was measured by using the salt dilution method, by instantaneous injections of a salt-water solution (of known volume and conductivity) based on the mass conservation principle (Elder et al., 1990; D'Agostino, 2004):

$$Q = C_s \frac{V_s}{\int_0^{t_0 + t_p} \left[\left(C(t) - C_b \right) \right] dt}$$

where:

Q = water discharge ($m^3\ s^{-1}$)

C_s= electrical conductivity of the salt-water solution ($\mu S\ cm^{-1}$)

V_s = volume of salt-water solution (m^3)

C = electrical conductivity measured at time t, ($\mu S\ cm^{-1}$)

C_b = electrical conductivity base value ($\mu S\ cm^{-1}$)

K = temperature calibration constant (~2.1642)

Conductivity was measured by a portable conductivity meter model WTW Cond340i with TetraCon 325 probe, storing data every 5 seconds. The assumptions of the methods are: the tracer is conservative during the passage of the measurement site; the flow is steady, that is, discharge and velocity do not vary with time but may vary spatially with stream location; the average water velocity and average tracer velocity are equal; the concentrations are sufficiently uniform laterally and vertically to allow spatial variation to be appropriately represented by a one-dimensional spatial axis. These assumption are normally fulfilled using salt (NaCl) as a tracer and injecting the diluted tracer (unsaturated solution of water and salt) at least a distance 10 times the stream width upstream of the conductivity meter (Elder et al., 1990).

The measurements of flow velocity were carried out using the salt tracer method. Two portable conductivity meters (same used for discharge measurement) were placed at the upstream and downstream end of each study reach. Their location was marked to be precisely identified in the field at each time of measurement, and their position was included in the topographical survey in order to calculate exact distances and elevation drops. As a tracer, a variable quantity of salt (NaCl) was mixed into a plastic bucket filled with stream water, avoiding saturation.

The salt mixture was then suddenly injected into the main stream at a distance of at least 10 channel widths upstream from the upper probe to promote adequate lateral mixing The time lag between the conductivity peaks recorded by the upstream and downstream instruments gives information on the average travel time of the flow, given that complete mixing was assured by injecting the tracer well upstream of the upper probe.

The conductivity probes' acquisition step of 5 seconds makes this measure of the travel time susceptible to some error, especially in shorter reaches. The distance between the probes was calculated based on the longitudinal profile surveys and was divided by travel time to determine mean flow velocity (Calkins and Dunne, 1970; Lee and Ferguson, 2002; Curran and Wohl, 2003; MacFarlane and Wohl, 2003; Mao et al., 2006).

Channel cross-section geometry parameters (wetted area, wetter perimeter, hydraulic radius) were calculated using the software WinXSPRO 3.0. These data will be combined with surveyed reach gradients and measured flow velocities to calculate Darcy-Weisbach friction factor.

Channel network

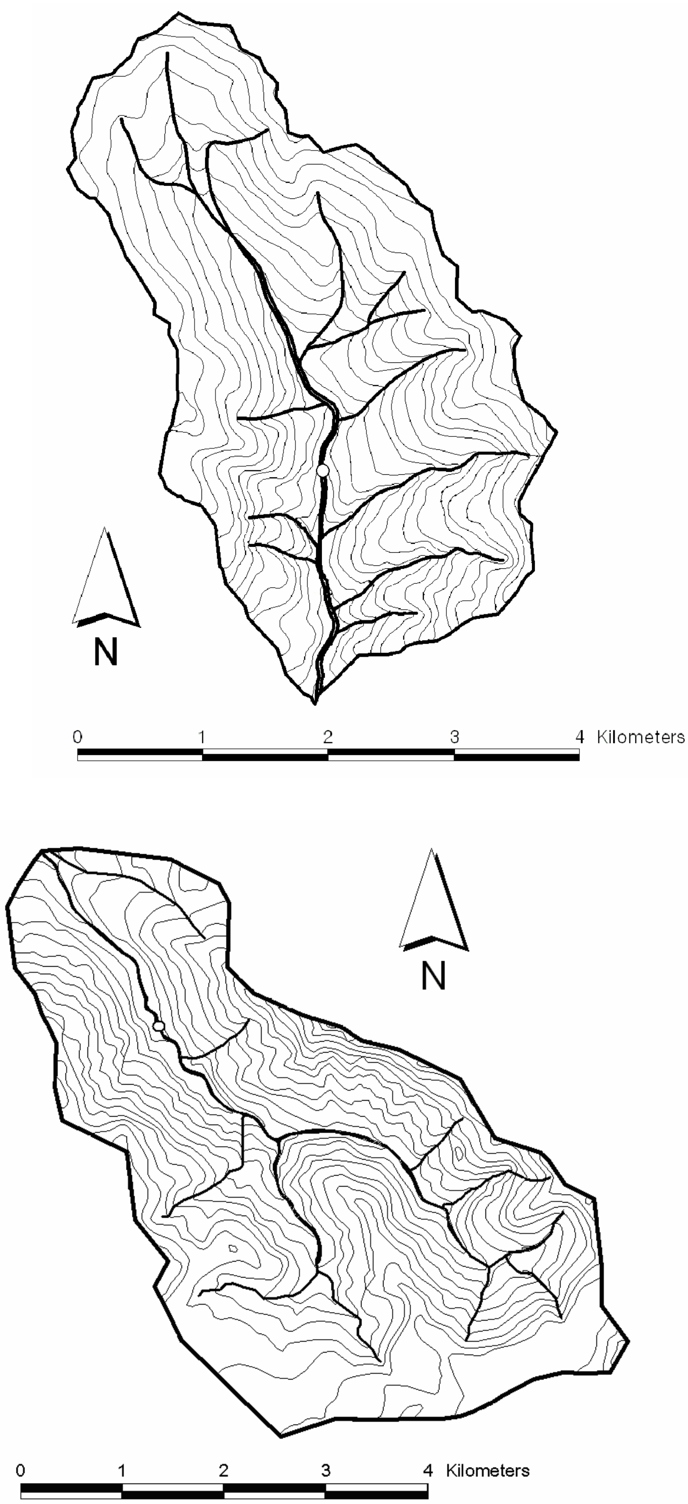
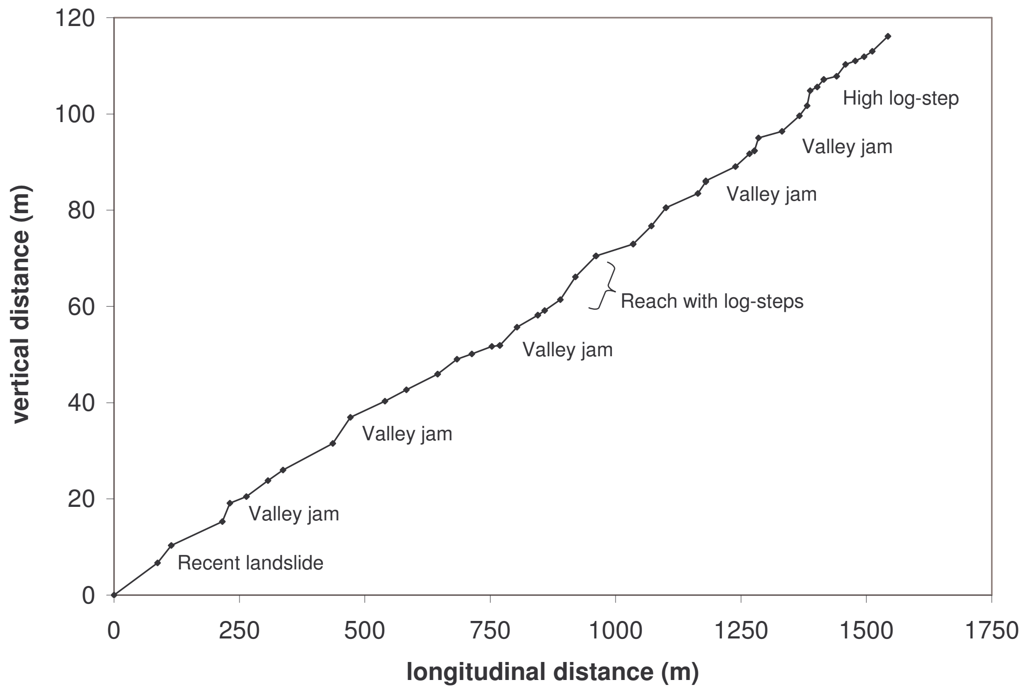


Figure 2 – Sketch of the two basins: Rio Toro (above) and Tres Arroyos (below). The circle along the main channel indicates the upstream end of the LWD survey.



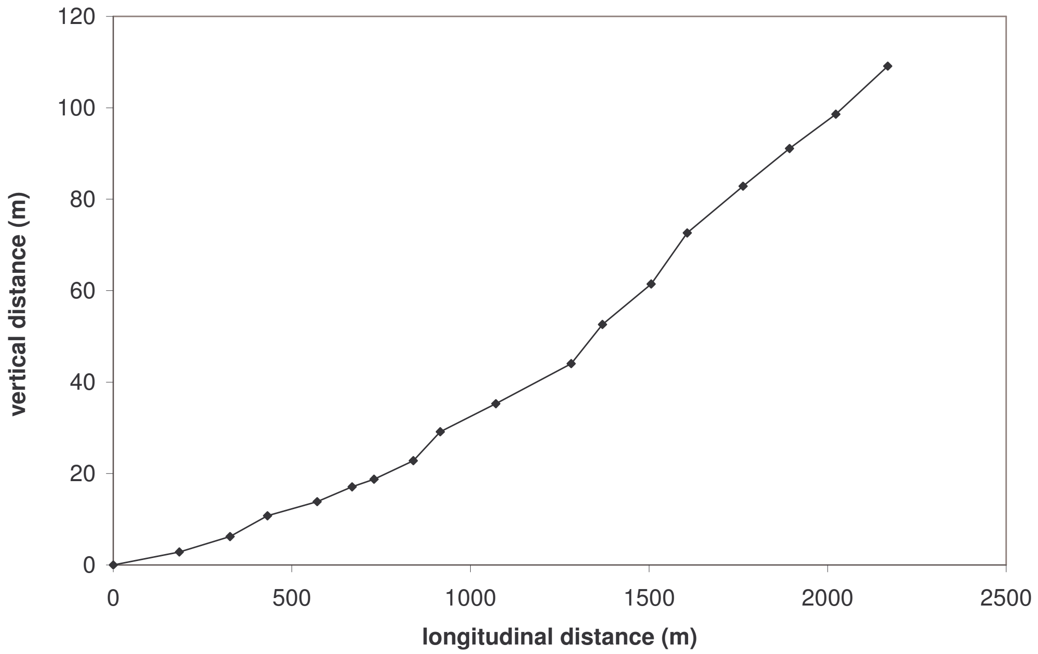


Figure 3 – The longitudinal profiles of the Tres Arroyos (above) and Rio Toro (below).

Data collected: summary

	Tres Arroyos	Toro
Basin and channel characteristics		
Basin Area (km^2)	9.1	11.1
Forest cover (%)	74	98
Forest type	Native	Native
Channel length (km)	4.9	7
Investigated channel length (km)	1.54	2.17
Average channel slope (m/m)	0.08	0.05
Average channel width (m)	7.7	11.9
LWD data		
Number LWD elements	2,615	758
Number of rootwad	118	17
Number of LWD jams	122	38
Mean LWD length (m)	3.25	3.56
Mean LWD diameter (m)	0.41	0.33
Mean LWD volume per element (m^3)	0.77	0.53
Total volume of LWD element (m^3)	1,848.88	400.76
Numer of log-steps and debris dam	33	-
Mean log-step/debris dam height (m)	1.1	-
Sediment stored behind log-step/debris dam (m^3)	1,957	-

Preliminary analysis

In the Tres Arroyos, the average LWD volume stored within the entire fluvial corridor (i.e. including channel margins) is impressive: based on channel length is 1,198 m^3 km^{-1}, and on bankfull channel area 1,530 m^3 ha^{-1}. Dimensions of LWD elements are up to 2.2 m in diameter and 26 m in length. The relative importance of nothofagus and araucaria is 94% and 6%, respectively. Average piece dimensions are 0.41 m in diameter and 3.25 m in length.. The average number of pieces is 1,550 per km of channel length and 1,979 per hectare of bankfull channel area. Comparably high values have been so far reported only for old-growth Douglas fir and redwood forests in the Pacific Northwest where is common to have 1,000 m^3 ha^{-1} of LWD. If only pieces within the bankfull channel are considered (i.e. excluding channel margins elements), the volume becomes 556 m^3 km^{-1} or 710 m^3 ha^{-1}, which is however very high, and the average spatial density is 786 pieces km^{-1} or 1,004 pieces ha^{-1}. Italian mountain streams of similar size feature only 30 - 60 m^3 ha^{-1}.

Natural mortality in the Tres Arroyos appears to be an important input mechanism, more than landslides or bank erosion, but massive inputs from debris flow channels represent critical locations of channel forcing. The morphological influence of such a high spatial density of large wood elements is very important, with the presence of large valley jams and high log-steps imparting the channel a macro-scale stepped profile (see Figure 3). The percentage of log-steps over the total steps is around 22%. The total potential energy dissipation due to LWD (log-steps and valley jams) is 27 % of the potential energy of the surveyed length. Sediment stored in the main channel thanks to LWD corresponds to approximately 150% of the annual basin sediment yield.

In the Rio Toro, the average LWD volume stored within the entire fluvial corridor, including channel margins, is less impressive than the Tres Arroyos: based on channel length is 184.84 m^3 km^{-1}, and on bankfull channel area 150 m^3 ha^{-1}. Dimensions of LWD elements are up to 1.2 m in diameter and 15 m in length. Average piece dimensions are 0.33 m in diameter and 3.56 m in length. The average number of pieces is 350 per km of channel length and 284 per hectare of bankfull channel area. If only pieces within the bankfull channel are considered (i.e. excluding channel margins elements), the volume becomes 148 m^3 km^{-1} or 121 m^3 ha^{-1}, and the average spatial density is 265 pieces km^{-1} or 215 pieces ha^{-1}. Natural mortality appears to be the dominant input mechanism, much more than landslides or bank erosion. The morphological influence of LWD in the Rio Toro is much smaller than in the Tres Arroyos, and neither log-steps or valley jams were observed. Therefore the longitudinal profile is not affected by LWD (see Figure 3).

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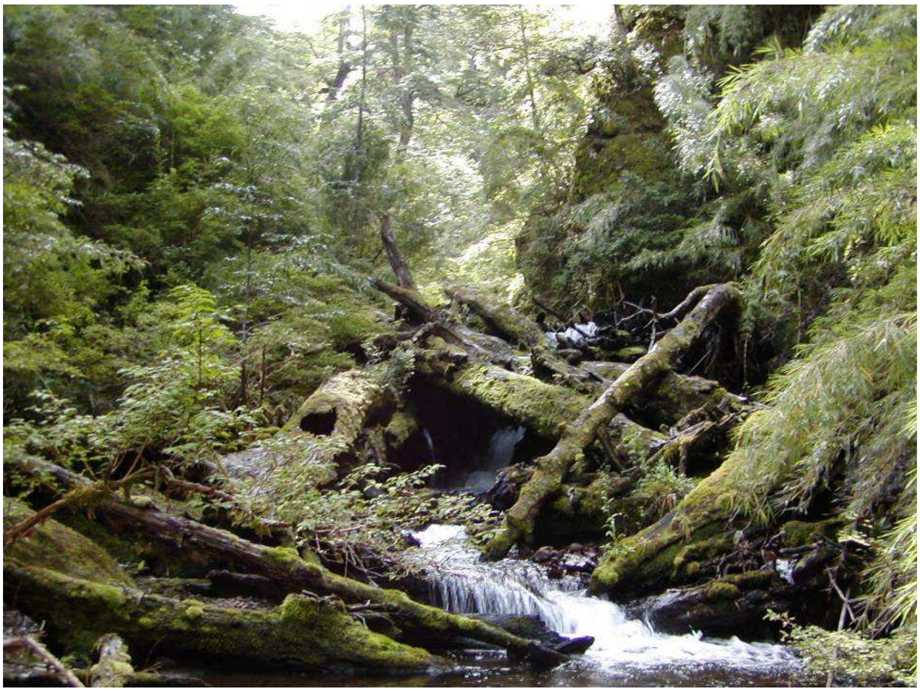
ANNEX: SELECTED PHOTOGRAPHS

Tres Arroyos



Rio Toro