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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 D13

Large Woody Debris Field Data and Methodology: Tierra del Fuego

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DIPARTIMENTO TERRITORIO E SISTEMI AGROFORESTALI

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Introduction

The field work was carried out in the Buena Esperanza basin (Ushuaia, Tierra del Fuego Argentina, Fig.1) from 9th February to 13th March 2006, and was led by the UNIPD team (Dr. Francesco Comiti, Dr. Luca Mao, PhD candidate Andrea Andreoli) with the permanent support offered by the SRNTF Subsecretaría de Recursos Hídricos (Eng. Adriana Urciolo, Eng. Rodolfo Iturraspe, Tech. Pablo Velásquez). In addition, Tech. Luis Opazo Urrutia from UACH and Eng. Sarah Burns from UNLP participated at the field works for 1 and 2 weeks, respectively.

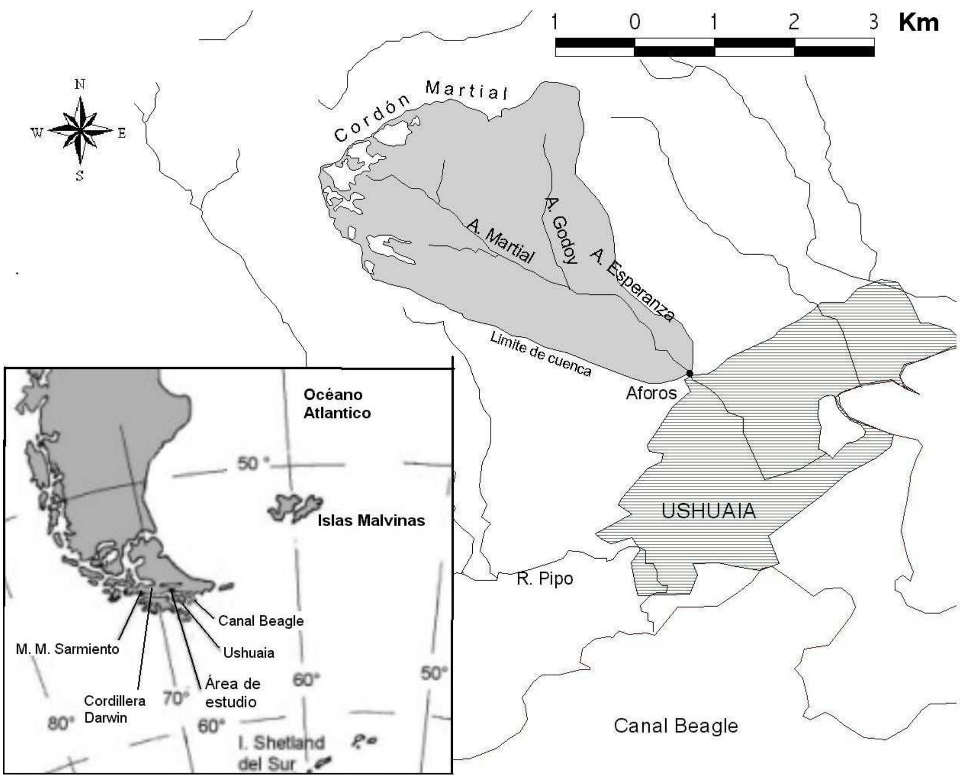


Figure 1 – Location map of the study basin

Methodology

Based on the preliminary field experience in Italian basins (Comiti et al., 2006; Mao et al., 2006), and on the 2005 field work in Chile (see D12), the following methodologies were applied and transferred from UNIPD to SRNTF and UNLP:

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 364 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. 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, and the Campbell CR510 with probe CS547, storing data every 1 second. 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 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

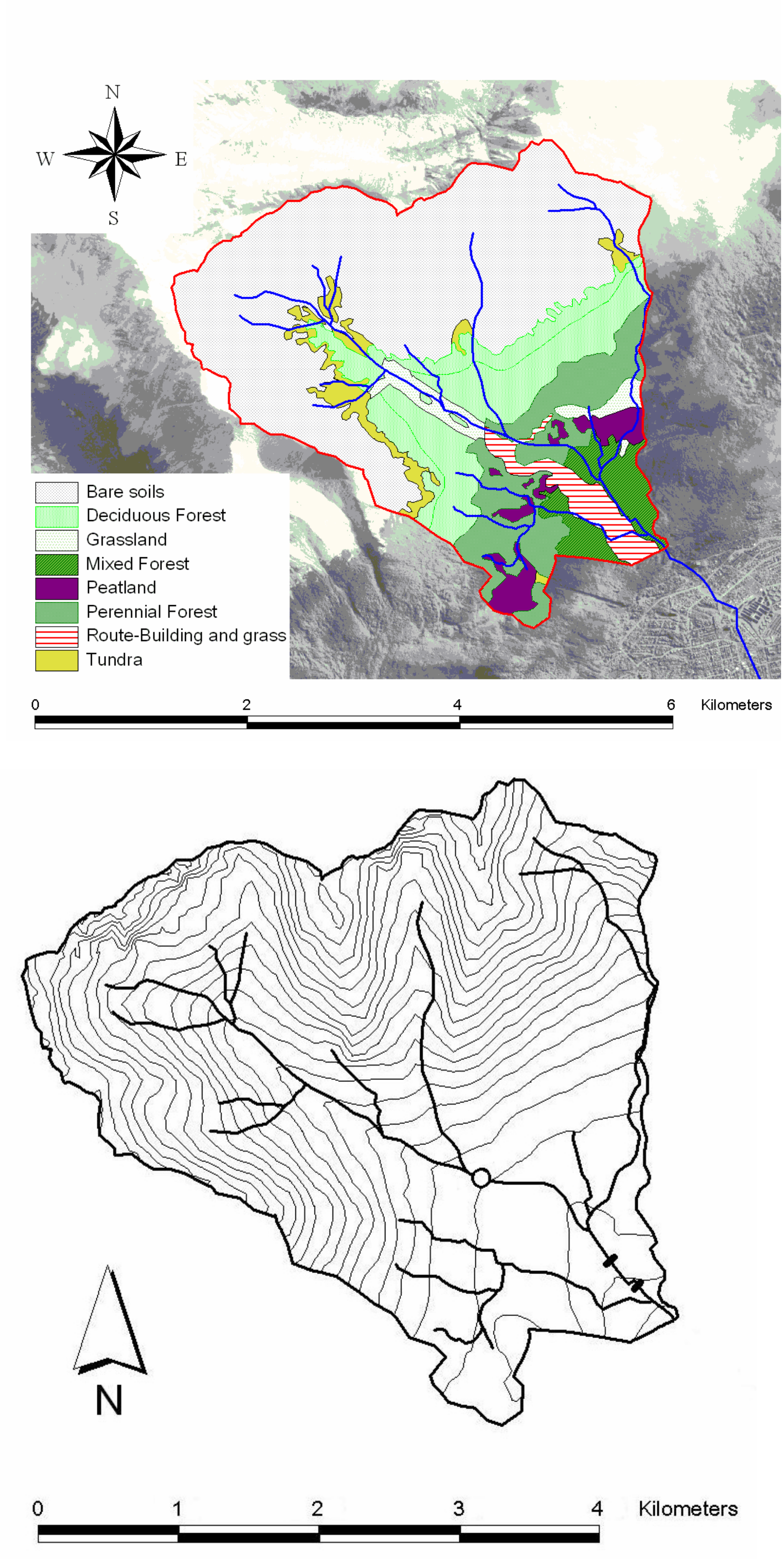
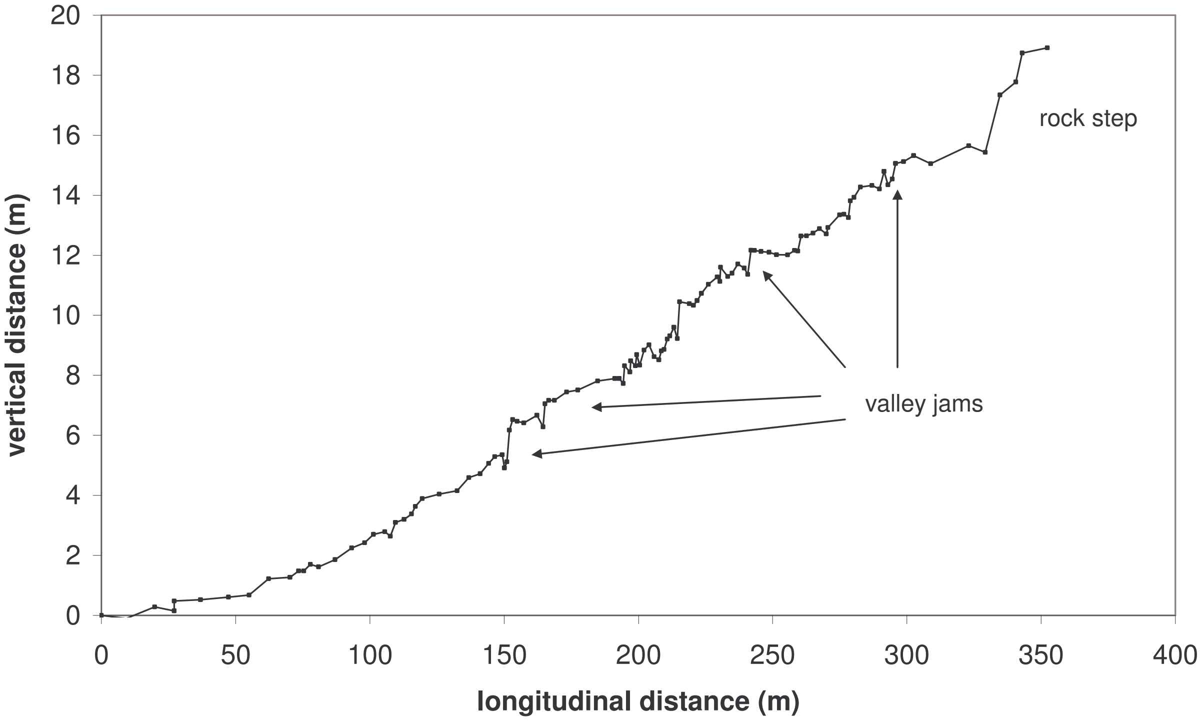


Figure 2 – Land use (above) and channel network (below) of the Buena Esperanza. The circle represents the upstream end section of the survey. The short stream segment within the two thick solid lines is a narrow, rough gorge which was not feasible to survey.



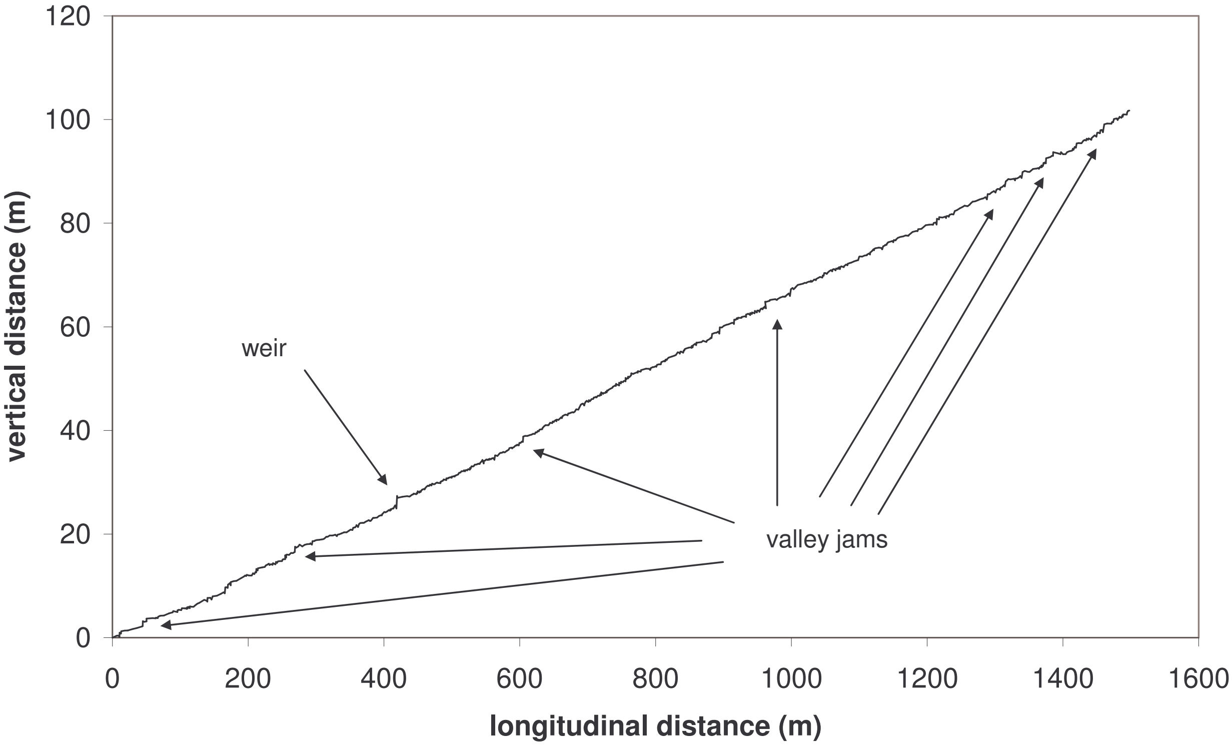


Figure 3 – Longitudinal profiles of the segment downstream (above) and upstream (below) of the gorge marked in Figure 2.

Data collected: summary

Basin and channel characteristics	
Basin Area (km^2)	12.9
Forest cover (%)	34
Forest type	Native
Investigated channel length (km)	1.85
Average channel slope (m/m)	0.065
Average channel width (m)	6.3
LWD data	
Number LWD elements	2,335
Number of rootwad	155
Number of LWD jams	113
Mean LWD length (m)	3.19
Mean LWD diameter (m)	0.19
Mean LWD volume per element (m^3)	0.15
Total volume of LWD element (m^3)	344.15
Number of log-steps and valley jams (debris dams)	59
Mean log-step/debris dam height (m)	0.54
Mean log-step/debris dam pool depth (m)	0.33
Mean log-step/debris dam pool length (m)	1.65
Channel length occupied by log-step/debris dam pools (%)	4
Channel length occupied by log-step/debris dam impoundments (%)	22.3
Channel elevation loss due to log-step/debris dam (%)	23.6
Sediment stored behind log-step/debris dam (m^3)	1,613

Preliminary analysis

The impacts of LWD on channel morphology and hydraulic are extremely important, and in turn their effect on sediment transport has been confirmed by the Potable Water Agency of Ushuaia in charge of managing the water intake structures located at the downstream end of the surveyed stream length, just upstream of the town. The Potable Water Agency occasionally cuts LWD into shorter pieces, aiming at reducing the risk of channel blockage. In fact, many LWD elements show to have been cut by chainsaw, thus altering the natural dimensions of woody debris inside the channel. However, the Water Agency has admitted that after these “maintenance operations” the sediment trapped upstream of the diversion weir increases considerably

The upper limit of the analysed channel length corresponds to the road end at the chairlift station: above this point the stream characteristics are heavily altered by the presence of the chairlift and of an adjacent ski slope. An intermediate reach within a gorge was impossible to walk and to measure due to the inaccessibility caused by vertical cliffs and high rock steps along the channel.

In the Buena Esperanza, the average LWD volume stored within the entire fluvial corridor (i.e. including channel margins) based on channel length is 186,5 m^3 km^{-1}, and on bankfull channel area 294.90 m^3 ha^{-1}. Dimensions of LWD elements are up to 0.9 m in diameter and 17 m in length. Average piece dimensions are 0.19 m in diameter and 3.19 m in length. The average number of pieces is 1,265 per km of channel length and 2000 per hectare of bankfull channel area.. If only pieces within the bankfull channel are considered (i.e. excluding channel margins elements), the volume becomes 74 m^3 km^{-1} or 116 m^3 ha^{-1}, and the average spatial density is 869 pieces km^{-1} or 1,374 pieces ha^{-1}.

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) with a total potential energy dissipation due to LWD (log-steps and valley jams) of about 24 % of the potential energy of the surveyed length.

References

Abbe, T.B., and D.R. Montgomery (2003), Patterns and processes of wood debris accumulation in the Queets river basin, Washington. *Geomorphology,* 51, 81-107.

Calkins, D., and T. Dunne (1970), A salt tracing method for measuring channel velocities in small mountain streams. *Journal of Hydrology*, 11, 379-392.

Comiti, F., Andreoli, A., Lenzi, M.A., and L. Mao (2006) Spatial density and characteristics of woody debris in five mountain rivers of the Dolomites (Italian Alps). *Geomorphology* (on-line)

Curran, J.H., and E.E. Wohl (2003), Large woody debris and flow resistance in step-pool channels, Cascade Range, Washington. *Geomorphology*, 51, (1-3), 141-157

D'Agostino, V. (2004), Sull'affidabilità delle misure di portata nei torrenti montani con il metodo della diluizione salina. *Proc. 29th Italian Congress of Hydraulics and Hydraulic Structures*, Trento, Italy, Sept. 7-10, 1005-1012.

Elder, K., R. Kattelmann, and R. Ferguson (1990), Refinements in dilution gauging for mountain streams. *IAHS Publ*., 193, 247-254.

Lee, A.J., and R.I. Ferguson (2002), Velocity and flow resistance in step-pool streams. G*eomorphology*, 46 (1-2), 59-71.

MacFarlane, W.A., and E.E. Wohl (2003), Influence of step composition on step geometry and flow resistance in step-pool streams of the Washington Cascades, *Water Resources Research*, 39 (2), 1037, doi:10.1029/2001WR001238

Mao, L., Comiti, F., and M.A. Lenzi (2006), La resistenza al flusso in un torrente montano ad elevata pendenza con morfologia a step-pool. *Rivista di Ingegneria Agraria,* Italy (in press).

Montgomery, D.R, and J.M. Buffington (1997), Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin*,109, 596-611.

ANNEX: SELECTED PHOTOGRAPHS