UNIVERSITY OF TRENTO - Italy
Department of Civil, Environmental and Mechanical Engineering

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Facoltà di Scienze e Tecnologie
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WOOD IN WORLD RIVERS

Proceedings of the Third International Conference WWR3 – 2015 (Extended Abstracts)

Edited by: Picco L., Lenzi M.A., Bertoldi W., Comiti F., Rigon E., Tonon A., Garcia Rama A., Ravazzolo D., Rainato R., Moretto J., Delai F.

Padova, Italy, 6 – 10 July 2015

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CONFERENCE TOPICS

Topic 1 - Wood and fluvial ecosystems

Wood in rivers is provided by shrubs and trees growing on vegetated bars, fluvial islands and floodplains. In-channel wood produces an increase in the structural and geomorphic complexity of river corridors and plays an important role in supporting their biodiversity and ecosystem functioning. This session contained contributions presenting results on the interaction between in-channel wood and the fluvial ecosystem, considering, e.g. the effect of wood on sediment structure and sorting, nutrient and energy cycling, formation of habitats, hydraulic refugia, and wood as a food sources for many organisms.

Topic 2 - Wood dynamics in rivers

The amount of wood occurring in rivers depends on a complex balance of wood input/recruitment, output/transport, and decay. Aim of this session is the discussion on recent research outcomes related to wood recruitment, transport, and deposition. Contributions focus on the role of different morphological settings, hydrological regimes, as well as wood characteristics, as drivers of the spatial and temporal variability of wood displacement.

Topic 3 - Techniques for wood monitoring and modeling

The ability to monitor and model wood dynamics is an essential step towards an improved management of the fluvial system. Several new surveying techniques have been developed during the last years, e.g. video monitoring, radio transmitters, tracking devices, as well as flume and numerical modeling. This session holds contributions on these recent methods of investigation, which may shed new light on our understanding of wood processes.

Topic 4 - Wood perception and management

In-channel wood may also induce risks for human populations, reducing channel conveyance and damaging structures. In order to ensure the positive contributions of wood to river ecosystems, and minimize potential hazards, an integrated approach to wood management along the entire river continuum is needed. This session explores recent experiences of wood management from the catchment scale to the design of infrastructures, in different environmental and human settings.

KEYNOTE SPEAKERS

Ellen E. WOHL, USA Department of Geosciences, Warner College of Natural Resources, Colorado State University

Ellen is a professor of geology at Colorado State University. She is a fluvial geomorphologist and her work has focused mainly on mountain and bedrock canyon rivers. For more than a decade, she has focused increasingly on the interactions among wood, channel and floodplain processes, and river ecosystem function, with a current research focus on wood in the context of organic carbon dynamics. Ellen is a fellow of the Geological Society of America and the American Geophysical Union. She has conducted field work on every continent.

Stanley GREGORY, USA Department of Fisheries & Wildlife, Oregon State University

Stan has been a faculty member in the Department of Fisheries & Wildlife at Oregon State University since 1981. Stan has been a leader of the Stream Team at Oregon State for more than two decades. He has studied streams, rivers, and lakes in the Pacific Northwest, and has been leading studies of the Willamette River for the last 20 years. His fields of expertise include stream ecosystems, landscape perspectives for stream ecosystems, influence of human activities on ecosystem structure and function, and development of restoration perspectives and practices that are consistent with natural stream processes.

Angela GURNELL, UK School of Geography, Queen Mary University of London

Angela is Professor of Physical Geography at Queen Mary University of London. Over her 40 year research career she has published over 160 journal papers, and 70 book chapters and full conference papers, mainly focussing on interactions among vegetation and hydrological and fluvial processes and their implications for sustainable river management. Her first paper on wood in fluvial systems was published in 1985. Since then her wood-related research has investigated how both dead wood and wood capable of sprouting interact with hydrological and fluvial processes to mould the characteristics and temporal dynamics of forested river landscapes.

Hervé PIEGAY, FRANCE National Center for Scientific Research, Lyon

Hervé is research professor at CNRS, Lyon, France, leading research on channel changes and their effects on riparian vegetation, and especially on wood in rivers. In the wood domain, his research field is mainly focused on large rivers and wood budgeting, developing research on wood monitoring from imagery, field surveys and experiment. Since 2010, he is in charge of the Rhône Observatory of Human and Environment Interactions, developing a strong partnership with most of the stakeholders involved on the river. He has recently coordinated an edited book on fluvial remote sensing for science and management with P. Carbonneau (2012).

Arturo ELOSEGI, SPAIN Department of Plant Biology and Ecology, University of the Basque Country, Bilbao

Arturo is professor of Ecology at the University of the Basque Country, in Bilbao. His research focuses on stream and river ecosystem functioning and how it is affected by human activities. He is particularly interested in the effects of forestry, water abstraction, pollution and channel modifications in ecosystem processes such as nutrient retention, organic matter breakdown or whole ecosystem metabolism, which are in turn the basis of important ecosystem services. He has been involved in the design, implementation and follow-up of several restoration processes where large wood has been used to improve stream habitat and functioning.

Session program

Tuesday 7, July

08.30 – 09.00 Registration

09.00 – 09.30 Welcome address

- Prof. Giancarlo Dalla Fontana, Director TeSAF Department-UNIPD
  Elected Vice-Chancellor University of Padova 2015-2021
- Prof. Mario Aristide Lenzi, TeSAF Department-UNIPD

09.30 – 10.00 Introductory Talk **Ellen E. WOHL** (USA): *"Bridging the Gaps: Wood Dynamics Across Time and Space in Diverse Rivers"*

Session 1 – Wood and Fluvial ecosystems

10.00 – 10.30 Keynote **Stan GREGORY** (USA): *"Scaling geomorphic and ecological effects of large wood in river networks"*

10.30 – 11.00 Coffee break

11.00 – 13.00 Oral session 1

1.1	**Dossi**, P. Leitner, W. Graf	The importance of large woody debris structures for benthic invertebrate communities along a longitudinal gradient of a lowland river in Austria
1.2	**G.C.L. David**, L.F. Devito, K. Munz	Linkages between fluvial wood and water quality downstrea beaver versus concrete dams in headwater streams Massachusetts
1.3	**M.R Sloat**, G.H. Reeves, K. Christiansen	Basin-scale availability of salmonid spawning gravel is more sensitive to wood loss than increases in mean annual flood disturbance in Tongass
1.4	**O. Shumilova**, K. Tockner, C. Zarfl	Floating organic material along river corridors, and the potential impact of hydropower development
1.5	**M.M. Schoor**, W.M. Liefveld, H. van Rheede, A. Sieben, P.P. Duijn, A. Klink, L.M. Dionisio Pires, W. Blaauwendraat	Reintroduction of large woody in navigable rivers: a pilot study to stimulate biodiversity within safety constraints
1.6	**F. Pilotto**, G.L. Harvey, G. Wharton, M.T. Pusch	Effects of single wood logs on surrounding patterns of flow, sediments and benthic invertebrate communities in a lowland river

13.00 – 14.00 Lunch

14.00 – 15.30 Poster session 1 and 2

Session 2 – Wood dynamics in rivers

15.30 – 16.00 Keynote **Angela GURNELL** (UK): "*Wood, trees and changing river landscapes*"

16.00 – 16.30 Coffee break

16.30 – 19.00 Oral session 2

2.1	**F. Nakamura**, J. Il Seo, T. Akasaka, Y. Yabuhara	Export of large wood and sediment at watershed scale, and predicted future changes of river and riparian ecosystems in Japan
2.2	**G.E. Grant**, L. Hempel, S.L. Lewis	Hydrologic regime controls pattern and architecture of woody debris in mountain streams
2.3	**S.J. Dixon**, D.A. Sear	Large Wood Dynamics in a Headwater Stream: Effects of Geomorphology on Transport
2.4	**J.B. Hinwood**, E.J. McLean	Large woody debris in an estuary: census data and transportation
2.5	**L. Saulino**, V. Pasquino, L. Todaro, A. Rita, P. Villani, G.B. Chirico, A. Saracino	Biomechanical aspects of native European black poplar (Populus nigra L.) under hydrodynamic loading in Southern Italy
2.6	**R.E. Bilby**, R.J. Danehy, K.K. Jones	Woodless rivers in the middle of forests

Wednesday 8, July

Session 3 – Techniques for wood monitoring and modeling

09.00 – 09.30 Keynote **Hervé PIEGAY** (FRANCE): "*Wood is good but it moves! Associated problems and research issues*"

09.30 – 10.30 Oral session 3

3.1	**P. Lemaire**, H. Piégay, B. MacVicar, L. Vaudor, C. Mouquet-Noppe, L. Tougne	An automatic video monitoring system for the visual quantification of driftwood in large rivers
3.2	**G. Valdebenito**, A. Iroumé, C. Jara, D. Alvarado, C. Fuentes	Large wood delivery from buried dead wood: the use of Ground Penetrating Radar (GPR) to characterize excess pyroclastic deposits in the Blanco River, southern Chile
3.3	**B. Wyzga**, P. Mikus, J. Zawiejska, M. Przebieda, V. Ruiz-Villanueva, R.J. Kaczka	Log transport and deposition during a flood in a mountain river: tracking experiment using radio telemetry

10.30 – 11.00 Coffee break

11.00 – 12.30 Oral session 3 continuation

3.4	**V. Ruiz-Villanueva**, B. Wyzga, H. Hajdukiewicz, P. Mikus, J. Zawiejska, M. Stoffel	Exploring wood dynamics in contrasting river morphologies: a numerical modelling approach
3.5	**M. Boivin**, T. Buffin-Bélanger, H. Piégay	Implementation and validation of large wood analysis for wood budgeting in a semi-alluvial river, the Saint-Jean River, Gaspésie, Canada
3.6	**N. Kramer**, E. Wohl	Timelapse imagery, crowdsourcing and wood transport on big rivers in the subarctic
3.7	**S. Pagliara,** S.M Kurdistani, L. Hassanabadi	Scour Morphology Downstream of Double-wing Log-Deflectors in Compare with Single-wing Log-Deflectors

12.30 – 13.30 Lunch

13.30 – 15.00 Poster session 3 and 4

Session 4 – Wood perception and management

15.00 – 15.30 Keynote **Arturo ELOSEGI** (SPAIN): "*The deception of perception: managing managers in an overpopulated world*"

15.30 – 16.00 Coffee break

16.00 – 18.30 Oral session 4

4.1	T. Sitzia, **L. Picco**, F. Comiti, L. Mao, D. Ravazzolo, A. Tonon, M.A. Lenzi	Sampling riparian vegetation and morphology with cross sectional transects: first results from three North-eastern Italian rivers
4.2	T. Gschnitzer, **B. Gems**, B. Mazzorana, M. Aufleger	Towards a robust assessment of bridge clogging processes in flood risk management
4.3	**G. Trentini**, G. Fossi	Management plan for riparian vegetation at the confluence of the Torrente Avisio river into the Adige River
4.4	**M. Seidel**, M. Mutz	Retention and stability of driftwood in a wood restored lowland stream
4.5	**A. Rimböck**	Woody debris in Bavarian torrential hazard analysis
4.6	**P.N. De Cicco**, E. Paris, L. Solari	Bridge clogging caused by woody debris: experimental analysis on the effect of pier shape
4.7	**F. Filippi**, P.G. Bensi, S. Pavan, F. Pellegrini, L. Petrella	Riparian vegetation management along the Secchia river (northern Italy) Experimenting sustainable management practices

18.30 – 19.00 Final Remarks and Best poster award

POSTER SESSION 1

1.7	N. Batz, P. Cherubini, S.N. Lane	Disentangling the driving variables of vegetated landforms in a braided-wandering alluvial forest
1.8	J. Moretto, F. Delai, L. Picco, R. Rainato, D. Ravazzolo, E. Rigon, A. Tonon, A. Garcia Rama, M.A. Lenzi	Medium- and short -term vegetation cover and channel dynamic in the Piave River
1.9	N.A Sutfin, B. Livers, E Wohl	Large wood-induced storage of sediment and organic carbon in mountainous streams of the Colorado Rocky Mountains, U.S.A.
1.10	T. Abbe, M. Ericsson, L. Embertson	Channel Incision and Floodplain abandonment due to historic wood removal in Washington State, USA
1.11	N. Kramer, E. Wohl	Driftcretions: driftwood and its legacy on the shoreline morphology of a large subarctic lake
1.12	J. Zawiejska, B. Wyzga, P. Mikus, R.J. Kaczka	Contrasting patterns of wood storage in mountain watercourses narrower and wider than the height of riparian trees
1.13	A. Veltri, G. Callegari, N. Cantasano, G. Pellicone, M. Russo	Ecosystem trend and evolution in fluvial morphology: an example in Calabria
1.14	A.N. Makhinov, S. Liu	Debris Dams on the Russian Far East Rivers

POSTER SESSION 2

2.7	J. Holloway, M. Rillig, A. Gurnell	Buried Live Wood and Root Systems of Riparian Black Poplar
2.8	F. Bettella, T. Michelini, V. D'Agostino, G.B. Bischetti	Small-scale simulations on the rule of the forest against debris flow
2.9	B. Mazzorana, O. Formaggioni, P. Macconi, N. Marangoni, A. Lucia Vela	Retracing wood dynamics during an extreme flood event in South Tyrol, Italy
2.10	P. Mikus, B. Wyzga	Monitoring of large wood supply and transport in Polish Carpathian watercourses
2.11	A. Iroumé, L. Mao, A, Andreoli, H. Ulloa, C. Ruz	Observations of in-stream large wood displacement in Chilean mountain channels
2.12	E. Bladé, V. Ruiz-Villanueva, M. Stoffel, G. Corestein	Challenges of numerical modelling of flow, sediment and wood in rivers
2.13	V. Ruiz-Villanueva, R. Stalder, W. Gostner, M. Paternolli, M. Stoffel	Wood responding to and driving hydromorphologic complexity in the near-natural River Sense (Switzerland)
2.14	A. Badoux. M. Bockli, D. Rickenmann, C. Rickli, V. Ruiz-Villanueva, S. Zurbrugg, M. Stoffel	Large wood transported during the exceptional flood event of 24 July 2014 in the Emme catchment (Switzerland)
2.15	F. Delai, I. Rutherfurd	The impact of riparian vegetation on bank retreat evolution: A comparison between different fluvial systems, the Piave (Italy) and the King (Australia) rivers
2.16	A. Lucia, D. Campana, E. Marchese, S. Brenier, F. Comiti	Large wood mobility in a mountain basin of North-eastern Italy
2.17	L. Picco, D. Ravazzolo, A. Tonon, M.A. Lenzi	Large Wood recruitment from floodplains and fluvial islands
2.18	N. Zhang, I. Rutherfurd, P. Marren	Impact of instream wood on bank erosion
2.19	D. Rickenmann, P. Waldner, T. Usbeck, D. Köchil, F. Sutter, C. Rickli, A. Badoux	Large wood transport during the 2005 flood events in Switzerland
2.20	E. Slowik-Opoka, D. Wronska-Walach	Significance of woody debris in the dynamic of bedload transport (Polish flysch Carpathians)

POSTER SESSION 3

3.8	H. Ulloa, A. Iroumé, L. Picco, D. Ravazzolo, L. Mao, M.A Lenzi	Large wood monitoring in a river affected by a volcanic eruption in the South of Chile: How accurate are the data from satellite images?
3.9	E.A. Chiaradia, A. Cislaghi, G.B. Bischetti	Modeling shallow landslides for LWD recruitment estimation
3.10	Z. Zhang, H. Piégay, P. Lemaire	Improvement and validation of video monitoring for floating wood under flood and wind condition in Ain river
3.11	A. Leuschner, F. Mattern, S. van Gasselt	Hydrogeomorphic characterization of forested fans at Lake Baikal, Siberia
3.12	D. Ravazzolo, L. Mao, L. Picco, A. Tonon, M.A Lenzi	Instantaneous movement of logs in two different impacted gravel-bed rivers
3.13	E. Rigon, A. Garcia Rama, R. Rainato, M.A. Lenzi	In-channel LW modelling in the Cordevole basin, Italy
3.14	A. Tonon, D. Ravazzolo, R. Rainato, L. Picco, J. Moretto, M.A. Lenzi	Assessing large wood and wood-jams volumes by TLS surveys
3.15	A. Tonon, L. Picco, D. Ravazzolo, R. Rainato, M.A. Lenzi	Methodological approach for assessing the Large Wood budget in large gravel-bed rivers (preliminary results)
3.16	L. Mao, W. Bertoldi, F. Comiti, A. Gurnell, D. Ravazzolo, M. Tal, M. Welber, S. Zanella	Flume modelling of large wood dynamics in braided channels characterised by different vegetation occurrence
3.17	F. Udali, W. Bertoldi	Photographic mapping of wood dynamics in the gravel-bed, braided Tagliamento River, Italy
3.18	V. Benacchio, H. Piégay, T. Buffin-Bélanger, L. Vaudor, K. Michel	Automatic imagery analysis to monitor wood flux in rivers (Rhône River, France)
3.19	B. Livers, K. Lininger, N. Kramer, E. Wohl	Porosity problems
3.20	D. Tullos, W. L'Hommedieu, C. Walter	Impacts of an engineered log jam on turbulence and momentum extraction across discharges
3.21	Y. Lai, D. Bandrowski, D.L. Smitm	Large Wood Precision Prototyping and 3D-Hydraulic CFD Modelling to Evaluate River Processes and Enhance Engineering Guidelines

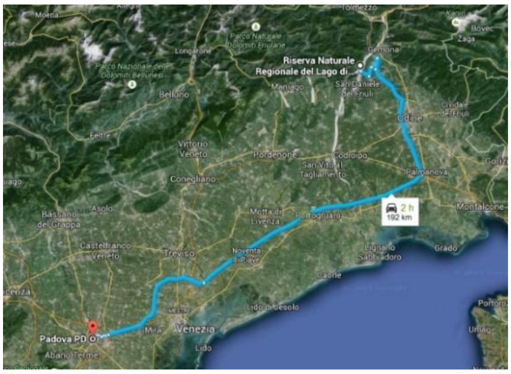
POSTER SESSION 4

4.8	T. Michelini, F. Bettella, V. D'Agostino	Protection forests against debris flow: field observations in mountain fans
4.9	S. Pagliara, M. Palermo	Controlled scour process due to debris accumulation at bridge piers
4.10	V. Leronni, G. Ricci, F. Gentile	Integrated use of remote sensing and geographic information systems in riparian vegetation and check dams monitoring in the Carapelle watershed (Northern Apulia, Southern Italy)
4.11	L. Mao, F. Ugalde, A. Iroumé	Large wood characteristics in native forest and pine plantation streams of the Costal Range of southern Chile
4.12	J.A. Mintegui, S. Fábregas, P. Huelin, J.C. Robredo	Assessment of the protective effects achieved in watersheds with water and forest restorations: application of the Arás torrent basin
4.13	M. Reich	Restoration of incised streams using large wood – long-term effects on a silt- and sand-bed stream in central Germany
4.14	V. Ruiz-Villanueva, E. Peñuela, A. Ollero, A. Diez-Herrero, I. Gutiérrez, D. Caetano, M.A. Perucha, H. Piégay, M. Stoffel	Perception of in-stream wood related to floods in Mountain Rivers in the Iberian Peninsula
4.15	A. Errico, F. Preti, L. Solari	The effect of flexible vegetation on flow in drainage channels: field surveys under different growth conditions
4.16	A. Ebone, A. Canavesio, F. Giannetti, P.G. Terzuolo	Management plan for riparian vegetation in the Orba Torrent, Alessandria, Piemonte Region, Italy
4.17	C. Cavazza, F. Lo Jacono	Management of riparian forest in the Reno River basin, Emilia-Romagna
4.18	C. Maxwell, R. Davidson, W. Fleming	Large wood in headwater intermittent channels key for basin scale dryland riparian system health

Technical and Cultural Visit

Monday 6, July

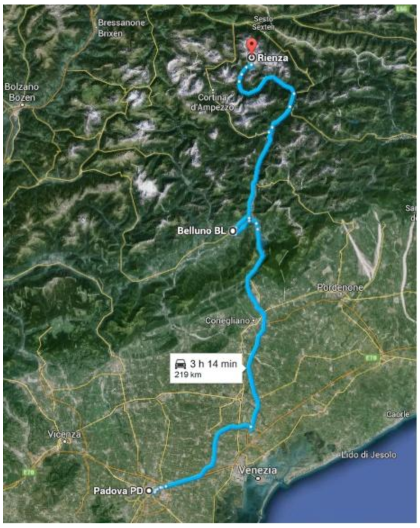
Pre-conference tour on the Tagliamento River (field trip assistants W. Bertoldi and L. Picco)



The Tagliamento River is located in the southern Alps of northeast Italy. Its headwater originates at 1195 m a.s.l. and flows for 178 km to the northern Adriatic Sea, thus forming a linking corridor between Alpine and Mediterranean zones. Its drainage basin covers 2871 km^2. A strong climate gradient exists along the length of the river that has great influence on precipitation, temperature, humidity, and consequently vegetation patterns. Because of the climate gradient, the floodplain of Tagliamento is an important biogeographical corridor with strong longitudinal, lateral and vertical connectivity, and high habitat heterogeneity (Tockner et al., 2003).

Thursday 9, Friday 10, July

Field excursion to Rienza (field trip assistants F. Comiti, A. Lucia and L. Picco) and Piave rivers (field trip assistants L. Picco, A. Tonon)



The Rienza river is located in the North of Italy (South Tyrol) and it flows for about 90 km to the Adige river. The drainage area of the Rienz basin at Bruneck is about 640 km^2 and the channel width is on average 10 m. Just upstream of Bruneck two wood retention structures were installed because many low bridges span the channel in the city, rendering the potential for wood clogging quite relevant (Mazzorana et al., 2011).

The Piave River is located in the North East of Italy and drains an area of 3899 km^2, mainly composed of sedimentary rocks (i.e. limestone, dolomite) (Surian, 1996). It flows for 222 km from the Dolomites (2037 m a.s.l.) to the mouth on the Adriatic Sea. The entire river basin has been altered by human activities since the 1930s (flow regulation, gravel mining, construction of dams) inducing important morphological channel responses (Comiti et al., 2011).

IN ALTERNATIVE

Thursday 9, July

Visit to the University of Padova “Palazzo del Bo” and the Botanic Garden (from 10.00 to 12.00 a.m.).

PREFACE

The First International Conference on “Wood in World Rivers” was held at the Oregon State University, USA, in October 2000. The papers presented at the conference were subsequently published in a famous book entitled The Ecology and Management of Wood in World Rivers. In August 2006, the Second International Conference took place at the University of Stirling, Scotland, and related papers were published on an special issue of Earth Surface Processes and Landforms.

The Third International Conference on Wood in World Rivers 2015 was born as a joint collaboration among the Universities of Padova, Bozen-Bolzano and Trento (Italy), with the aim to present and discuss the emerging perspectives related with in-stream wood and to disseminate its relevance – as well as that of riparian forests - for the ecology, geomorphology and management of rivers.

The Third International Conference on Wood in World Rivers was held at the University of Padova, Italy, one of the oldest university of the world, founded in 1222. The conference venue was located in the historical center of Padova, but pre- and post-conference trips to the Alpine Rivers were offered.

The WWR3-2015, was aimed to analyze the importance of wood of all sizes, both living and dead, and the riparian forests which produce wood, a crucial element for geomorphology, ecology and management of rivers. Main purposes were to: synthesize the knowledge on the physical dynamics and ecological interactions of wood in streams and rivers in different geographical regions; create a framework for interpreting and applying research results and management systems; assess physical and biological responses of large wood in stream restoration; explore links between physical and ecological dynamics of large wood, resource management systems and the communities and cultures in which they are applied.

WWR3-2015 was aimed to promote also a connection between geosciences and ecology which represents a challenging aspect for restoration purposes. Following the line of the first two conferences on Wood in World Rivers, we wished to attract a wide assembly of wood lovers and to consolidate the idea to have regular International Conferences and Meetings. The conference topics covered all those interdisciplinary approaches which are characteristic for research studies and applications to disturbed and un-disturbed river and stream environments. An important goal of the 3rd International WWR Conference was to promote and increase the relationships between scientists and professional operators. The integration of these two worlds has had positive effects on many fields such as surveys, monitoring techniques, design procedures, implementation of projects.

The 3rd International Conference also offered an extraordinary opportunity for scientists, agencies and companies to meet and improve together the-state-of-the-art of Wood in World Rivers.

WWR3 – 2015 Key Figures

- 5 Keynote speakers
- 73 Papers selected
- 90 Participants
- 2 Technical tours

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Large wood in headwater intermittent channels key for basin scale dryland riparian system health

Introductory talk

Keynote speaker: **Ellen E. Wohl**

Presentation title: Bridging the Gaps: Wood Dynamics Across Time and Space in Diverse Rivers

Short presentation

An extensive body of literature has accumulated on wood in rivers during the past half century. We can draw on this information to develop conceptual models of wood recruitment, transport, and storage in channels and floodplains, and the range of physical and ecological effects of wood. We remain challenged, however, by issues central to scientific understanding and river management. These issues include quantifying the natural range of variability in wood loads within distinct segments of a drainage basin and between drainage basins in diverse biomes and geomorphic settings, and quantitatively predicting physical and ecological effects of changes in wood load.

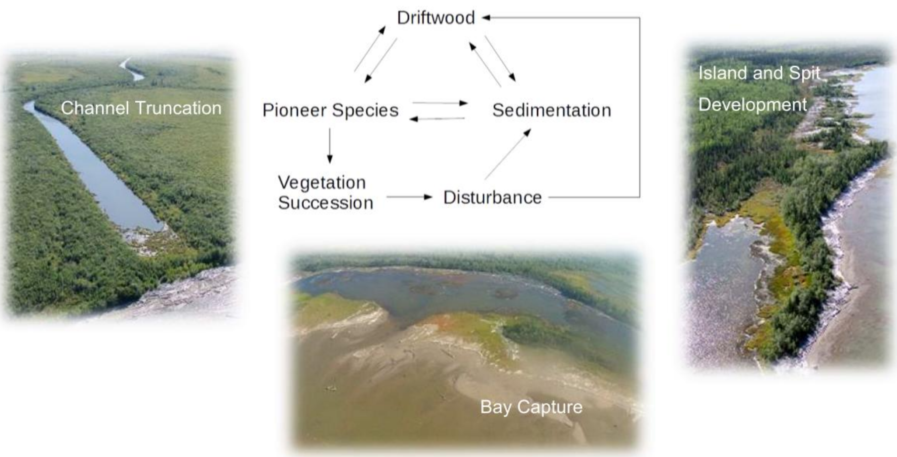
TOPIC 1 - Wood and fluvial ecosystems

Keynote speaker: **Stanley GREGORY**

Presentation title: Scaling geomorphic and ecological effects of large wood in river networks

Short presentation

A major conceptual challenge is scaling of geomorphic and ecological functions of wood across river networks. Sizes of large wood and sizes of river channels are important determinants of wood dynamics along a river system. Storage and transport processes change along a river as a function of the ratio of wood length and channel width. In larger rivers, accumulations may be relatively frequent if normalized by channel dimensions. In extremely large rivers, wood is floated and redistributed, resulting in less frequent accumulations. Ecological interactions with large wood are shaped by differences in wood dynamics and network patterns of biological processes.



Conceptualization of feedbacks between driftwood, sedimentation and plant succession. Photographs illustrate several landforms resulting from driftcretions. Photos were taken on the shores of the Great Slave Lake, Northwest Territories, Canada (62.5N, 114W, WGS 84) on August 29, 2014 from a low flying aircraft (In: *Driftcretions: Driftwood and its legacy on the shoreline morphology of a large subarctic lake. N. Kramer, E. Wohl*)

The importance of large woody debris structures for benthic invertebrate communities along a longitudinal gradient of a lowland river in Austria

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Abstract

The aim of the following work is to analyze the importance of Large Woody Debris (LWD) for benthic invertebrates along the longitudinal gradient of a lowland river, the Lafnitz River. The river is located in the southeastern part of Austria and has a near natural character and riparian vegetation, with a high diversity of woody debris structures. Differences in benthic invertebrates on lithal and xylal substrates were documented at ten sites along its longitudinal gradient. The results of the study show significant differences in taxa composition between these two substrate types. A distinct correlation between the distance from spring and the number of the taxa exclusively found on xylal were observed. The results of this study underline the importance of LWD for biodiversity and conservation issues, especially in potamal sections.

Keywords: *Large Woody Debris; benthic invertebrates; longitudinal gradient; Austria.*

Introduction

Large woody debris (LWD) influences not only the hydraulic (e.g. Manners et al., 2007; Shields et al. 2001) and morphological situation, (e.g. Gerhard & Reich, 2000; Kail et al. 2007) but also the sediment and nutrient budget (e.g. Bilby & Likens, 1980; Gurnell et al. 1995) of a river section. In addition to these effects of LWD on the surrounding habitat diversity, submerged wood is an important habitat for benthic invertebrates and fish, especially in the lower parts of a river (e.g. Hering & Reich, 1997; Smock et al., 1989). Hering & Reich (1997) listed 44 benthic invertebrate taxa closely linked to submerged LWD structures in Central Europe. Due to bank fixation, removal of riparian vegetation and instream depositions of LWD in order to provide e.g. flood safety, these important habitats have disappeared widely in Central European streams and rivers. The aims of this study, performed within the BIO_CLIC project are: (1) to investigate differences in the colonization of lithal and xylal substrates of the benthic community regarding biodiversity and density and (2), to evaluate the differences of the colonization between these substrate types along a longitudinal gradient of a river.

Study Area

The study area covers the whole course of the Lafnitz River, which is situated in the South-East of Austria. The upper section of the river is part of the ecoregion "Alps" and the middle to lower section is part of the ecoregion "Hungarian Plains". The Lafnitz River is one of the last near-natural rivers in Central Europe with intact hydromorphological dynamics, near-natural riparian vegetation and naturally occurring LWD accumulations along its course. Ten investigation sites were chosen along its 110 km river length, covering the entire Austrian stretch.

Materials and Methods

Xylal and lithal substrates were sampled separately at the sites to investigate differences in the impact of LWD-structures on the benthic invertebrate community along the longitudinal gradient. Lithal substrate sampling was carried out using a modified form of the Multi-Habitat-Sampling method according to the AQEM-consortium (2002), considering only minerogenic substrates. For xylal substrate sampling, three independent LWD parts were taken at each site. All organisms were carefully brushed/washed from the parts into a 500µm kick-net. In addition, all parts sampled were taken to the laboratory for further examination. All parts were measured (length, width, volume) and their surface was calculated to compare abundances of both substrate types.

Results

The taxonomic composition from each site was analyzed in order to determine discrete longitudinal zonation patterns. Changes in the overall benthic coenosis of the entire river course as well as the distribution of selected species along the river were considered. Based on the species composition, four segments became obvious (Fig. 1). The spring fauna (e.g. Trichoptera: *Apatania fimbriata*; Plecoptera: *Isoperla tripartita*) forms a distinctive community. Adjacent sites (L_2_MM - L_5a_NS) represent the rhithral section (meta-to hyporhithral; e.g. Plecoptera: *Siphonoperla torrentium*; Trichoptera: *Allogamus auricollis*, *Ecclisopteryx dalecarlica*) followed by the potamal region (L_6_WA - L_8_DK; e.g. Trichoptera: *Hydropsche siltalai*, *Lepidostoma basale*; Plecoptera: *Brachyptera braueri*). Due to the presence of numerous exclusive taxa (e.g. Ephemeroptera: *Ametropus fragilis*; Plecoptera: *Agnetina elegantula*, *Besdolus ventralis*, *Taenopteryx nebulosa*), the most downstream site was classified as a discrete segment.

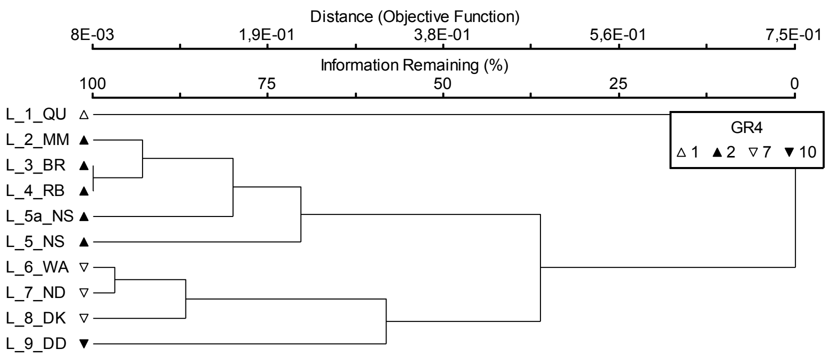

Figure 1: Results of the Cluster Analysis (Distance Measure: Soerensen; Linkage Method: Flexible Beta -0,25); Overlay: 4 Groups, numbers are indicating the first site of each group (Dossi et al., in prep.)

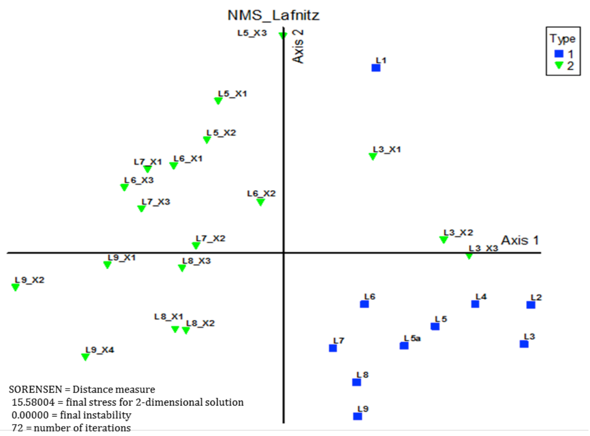

Figure 2: NMS-Analysis of the benthic community (lithal-blue and xylal-green) (Dossi, 2014)

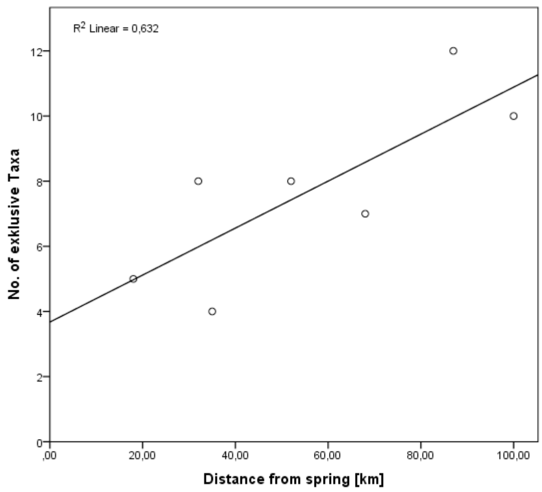

Figure 3: Correlation between the distance from spring and the number of xylobiont taxa (Dossi, 2014.)

The differences in the colonization of substrate types were evaluated using different similarity indices, indicator species- and multidimensional scaling-analysis. Taxa composition is strongly influenced by substrate type (Fig. 2) and impact of LWD increases with river length. The results show a clear correlation between the longitudinal gradient of the river and the number of xylobiont species. While in the upper reach (rhithral section) the majority of taxa colonized both types of habitats equally (xylal and lithal substrates respectively), the number of taxa living exclusively on LWD increased steadily with distance from spring. Out of 25 taxa exclusively found at xylal habitats, only five were documented at the upper course, while twelve were found downstream in the potamal section (Fig. 3).

Discussion and Conclusion

The results of this study emphasize the importance of LWD structures beyond overall river morphology. The presence of woody debris structures, especially in potamal sections, is directly linked with a considerable increase in aquatic biodiversity. In addition, the exclusive occurrence of taxa found on woody debris (xylobiont species) shows the unique and irreplaceable status of LWD as a habitat in riverine landscapes. These findings are underlined by the presence of *Macronychus quadrituberculatus* (Coleoptera) and *Agnetina elegantula* (Plecoptera), which are very rare in Central Europe. Due to the major influence on surrounding habitat structure and overall river dynamics (e.g. Gerhard & Reich, 2000; Gurnell et al., 1995; Kail et al., 2007) as well as their function as unique habitats for xylobiont species, LWD structures are valuable assets in the process of river revitalization, especially when concerning the high costs of conventional revitalization methods (Gunkel, 1996). Even in areas as densely populated as Central Europe, about one third of the degraded rivers could be restored using LWD structures (Kail & Hering, 2005).

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Linkages between fluvial wood and water quality downstream of beaver versus concrete dams in headwater streams in Massachusetts

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Abstract

Beavers are important ecosystem engineers because of their ability to build dams that create low flow zones in the river, increasing the height of water tables, and often creating wetland habitat adjacent to the channel. Beaver dam habitat can increase the interaction between groundwater and surface water, improving water quality, and increasing the cycling of nutrients. It is not well understood if these changes in water quality are unique to beaver dams or if small concrete dams can have similar effects. We hypothesized that beaver dams, as opposed to concrete dams, would increase wood loads in rivers in Massachusetts, therefore increasing biogeochemical cycling of material and water quality. We surveyed water quality, in-channel wood, and geomorphic parameters in four headwater watersheds in Massachusetts, two with beaver activity and two with artificial dams, to better understand wood function in watersheds that are disconnected by dams. Two to three reaches were surveyed in each watershed. Beaver dams increased large wood. In reaches concrete dams, wood was input where the channel was actively widening or incising, demonstrating the importance of local controls on wood recruitment. Wood load was not directly connected to water quality parameters such as dissolved oxygen (DO) and ammonium, but did influence bed characteristics such as pool formation. DO was inversely correlated with depth in the majority of reaches, but then switched to a biotic control in watersheds with high ammonium concentration. Therefore, the beaver meadow complex is effective in increasing wood loads and processing contaminants out of the stream.

Keywords: *Large wood; Beavers; Dams; Dissolved Oxygen.*

Introduction

Large wood found in stream channels is an essential component of stream ecosystems by providing habitat and refuges for aquatic organisms, increasing accumulation of organic matter, and increasing the processing of nutrients and other materials. Wood is an essential component of the aquatic ecosystem, particularly for beavers, who use the material to build dams and develop wetland habitat which benefits many other fish, bird, and mammal species (Fig. 1). We hypothesized that reach-scale changes in dissolved oxygen (DO) and ammonium (NH_4^+) were connected to wood load and distribution. We further hypothesize that concrete dams will reduce wood loads and create zones of decreased water quality.

Study Area

Streams in four headwater watersheds in Massachusetts were surveyed to investigate downstream effects of beaver dams, versus concrete dams (Table 1). Two watersheds contained beaver dams along with concrete dams, and two watersheds contained only concrete structures. Mixed coniferous and deciduous forests make up the riparian zone along the banks of each of the study sites. The deciduous trees were mainly beech, birch and maple and the coniferous trees are spruces and pines. The forest in Massachusetts is less than 200 years old, having regrown after abandonment of farms in the mid-1800s and early 1900s.

Figure 1: Beaver meadow complex along a headwater stream in Massachusetts. The beaver meadow is formed by multiple beaver dams and creates a wetland habitat with multi-thread channel. In the center of this picture is wood left behind from a collapsed dam.

Watersheds that were included in the study are all state park or conservation land in Massachusetts. The concrete dams that are on these lands were built over 50-100 years ago. Beavers were extinct in Massachusetts until the mid-1940s, when they were reintroduced in the western part of the state. In 2001, the beaver population was estimated to have risen to 70,000 (Mass.gov, 2014).

Table 1: Summary table showing reach characteristics for watersheds that include beaver dams, BSR and PHB, and watersheds with artificial dams, NOA and HP. PHB has both beaver dams and artificial dams.

Watershed	Drainage Area (km^2)	Reach Name[1]	Reach Description	Gradient (m/m)	Wood Load (m^3/m^2)	D_{84} (mm)	DO (mg/l)	NH_4^+ (mg/l)
Bear Swamp Reservation (BSR)	0.9	BSR US	Upstream of beaver meadow	0.076	0.001	105.2	8.57*	0.27
		BSR DS	Downstream of beaver meadow	0.004	0.006	49.0	6.60	0.23
Pearl Hill Brook (PHB)	13.1	PHB US	Upstream of beaver meadow	0.025	0.001	161.8	7.71*	1.11
		PHB MS	Downstream of beaver meadow	0.016	0.004	84.5	7.12	0.61
		PHB DS	Downstream of artificial dam	0.029	0.003	196.7	8.74	1.44
Noanet Woodlands (NOA)	1.6	NOA US	Upstream of artificial dam	0.007	0.003	34.0	6.85*	0.39
		NOA MS	Downstream of 1st artificial dam	0.013	0.001	54.9	6.64*	0.32
		NOA DS	Downstream of 2nd artificial dam	0.035	0.004	32.7	8.02	0.55
Harold Parker (HP)	0.7	HP DS	Downstream of artificial dam	0.026	0.008	84.6	6.45*	0.96

[1]Reaches are labeled in order going downstream with US = upstream reach; MS = midstream reach; DS = downstream reach.

*DO inversely correlated with depth along the longitudinal profile for these reaches.

Materials and Methods

Geomorphic and water quality surveys were conducted up- and downstream of both the beaver and artificial dams. Geomorphic surveys included a total station survey of the channel bed elevation. The water depth, along with the bed elevation, was measured at each point along the longitudinal profile. Reaches ranged in size from 10 to 50 meters, depending on bed geomorphic characteristics. Two representative cross sections were surveyed at each site. Cross-section data were used to quantify average channel width, depth, and hydraulic radius on the day of the survey as well as the bankfull measurements. Gradients were calculated using the longitudinal profile survey. Grain size was determined using a pebble count of 300 pebbles. The total station was also used to survey the location of large wood in the channel. The wood survey included information about the log diameter, spatial distribution, accumulation type, decay class, and stability (Wohl et al., 2010).

Water quality data was collected along the longitudinal profile. Dissolved oxygen (DO), ammonium (NH_4^+) concentration, and temperature were measured with the YSI Professional Series probes at each total station survey point. NH_4^+ was used to assess which regions have reduced water quality. An Extech light intensity meter was used to record light levels (Lux) along with each DO measurement. Discharge was determined using a single station salt dilution method with YSI conductivity probes. Average velocity was then calculated using the cross section data.

Results

Generally, wood loads increased downstream of the beaver dams (Table 1), with the majority of pieces having been floated from upstream. The local instabilities increased wood inputs from the riparian zone. Wood was not found to be directly linked to DO, other than the development of pools being spatially correlated with wood jams.

At the reach-scale, DO varied between abiotic and biotic controls, depending on upstream nutrient dynamics. NH_4^+ concentrations also varied in the downstream direction, with one of the largest changes occurring in PHB. The increase furthest downstream is most likely from drainage off of an old industrial park. DO was found to be inversely correlated with depth in reaches that were up- and downstream of concrete dams. The reaches that did not have a connection between DO and depth were downstream of a beaver meadow complex. DO was not found to be correlated with light intensity or temperature.

Discussions and Conclusions

Wood loads varied based on local controls (Wohl and Cadol, 2011). Localized instabilities increased the recruitment of wood from the riparian zone. Concrete dams reduced the likelihood of wood being floated downstream into the reaches, whereas beaver dams increased wood inputs from upstream.

Ammonium levels were high upstream of the beaver meadow at PHB and decreased drastically downstream of the beaver meadow, indicating that the meadow effectively cycled the contaminants out of the water. Likewise, DO was no longer inversely correlated with depth downstream of the beaver meadow, indicating that the control on DO concentration switched from an abiotic control to a biotic control.

Wood load was not found to be directly connected to DO or NH_4^+ concentrations. On the other hand, reaches with larger wood jams were found to have deeper pools. In many of the reaches, the deeper water was correlated with lower concentrations of DO. Therefore, wood loads are interpreted as being an important component of the channel geomorphic structure, which can then alter water quality parameters.

Acknowledgments

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Basin-scale availability of salmonid spawning gravel is more sensitive to wood loss than to increases in mean annual flood disturbance in Tongass National Forest, Alaska

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Abstract

We estimate the influence of instream wood on Pacific salmon spawning habitat under contemporary and projected increases in mean annual flood magnitudes expected with climate-change for Tongass National Forest, Alaska streams. We parameterized predictive models of reach-average D_{50} with field data and digital elevation models to determine basin-scale spawning gravel availability for six combinations of flood magnitude and wood occurrence. Our simulations suggest that streambed coarsening as the result of wood loss from rivers could have a much greater effect on salmon spawning habitat availability than would increases in mean annual flood magnitudes of up to 30%. Our analysis provides a useful basin-scale perspective on the potential impact of wood loss (or benefit of wood restoration) for salmon spawning gravel availability relative to the effects of climate-induced increases in flood disturbance in southeast Alaska.

Keywords: *climate change; flood disturbance; salmon spawning gravel; wood roughness.*

Introduction

Pacific salmon (*Oncorhynchus* spp.) are integral ecological, economic, and cultural components of the Tongass National Forest (TNF) in southeast Alaska. Species and populations are currently well distributed across TNF and most are generally productive and healthy but managers are concerned that a legacy of loss of wood from rivers from past logging and climate-induced increases in mean annual flood magnitudes may impact salmon spawning gravel availability. In this paper, we combine digital elevation models and field measurements to estimate the influence of instream wood on basin-scale salmon spawning gravel availability under contemporary and projected increases in mean annual flood magnitudes.

Study Area

Our study included watersheds of the Tongass National Forest (TNF), located in southeastern Alaska, USA. TNF extends from Dixon Entrance in the south (54°N, 132°W) to Yakutat Bay (60°N, 140°W) in the north, and is bordered on the east by Canada and on the west by the Gulf of Alaska. It covers 6.8 million hectares, 80% of the land in southeast Alaska. TNF includes a narrow mainland strip of steep, rugged mountains and icefields and more than 1,000 offshore islands known as the Alexander Archipelago.

Materials and Methods

We adapted a general framework (Buffington et al. 2004) to examine the effects of channel type and associated hydraulic roughness on salmon spawning gravel availability under contemporary and predicted future flood disturbance regimes. This framework incorporates digital elevation models and field measurements of bankfull channel morphometry to predict streambed grain size and salmon spawning gravel availability. We predicted reach-average median streambed grain size (D_{50}) following methods developed by

Buffington et al. (2004): $D_{50} = (\rho hS)^{1-n}/[(\rho_s-\rho)kg^n]$, (1)

where h is bankfull depth, g is gravitational acceleration, S is channel slope, ρ_s and ρ are sediment (2650 kg·m^{-3}·s–1) and fluid densities (1000 kg·m^{-3}·s^{-1}), respectively. The terms k and n are empirical values relating bankfull Shields stress (τ_{bf}*) and total bankfull shear stress (τ): $\tau_{bf}^* = k\,\tau^n$. (2)

Values for k and n vary by channel type and are given for Pacific Northwest mountain drainages in Fig. 1.

To estimate the effect of instream wood on salmon spawning gravel availability, we first predict the occurrence of pool-riffle and plane-bed channel reaches within TNF stream networks based on corresponding channel slope breaks of 2% and 4.5%, respectively (TNF, unpublished data). We then use values for k and n corresponding to pool-riffle and plane-bed channel types to predict with equation 1 which reaches would have reach-average D_{50} within the preferred range for salmon spawning (i.e., 10 – 50 mm) in the absence of instream wood. Next, for those reaches not predicted to support salmon spawning habitat without instream wood, we use values of k and n corresponding with wood-forced pool-riffle channels (Fig. 1) to determine whether an increase in hydraulic roughness with the addition of wood could result in reach-average D_{50} within the preferred range for salmon spawning. We then analyze differences in basin-scale availability of salmon spawning gravel with and without instream wood. Finally, we repeat these steps under scenarios in which mean annual flood magnitudes increase 20 and 30%. These flood magnitude increases approximate the predicted hydrological responses under mid-to-late 21st century climate scenarios for southeast Alaska.

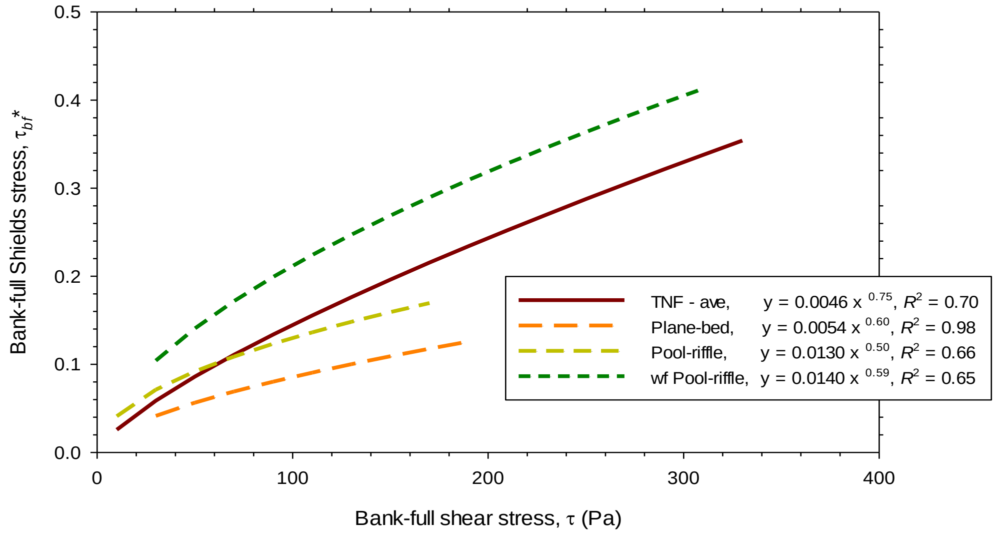

Figure 1: Bankfull Shields stress as a function of bankfull shear stress and channel type in Pacific Northwest and Tongass National Forest, southeast Alaska streams. The average relationship among all channel types in Tongass National Forest streams (TNF-ave) is also plotted. Data from Tongass National Forest (n = 372; TNF unpublished data) and Buffington et al. (2004).

Results

Our simulations suggest that streambed coarsening as the result of wood loss from rivers could have a much greater effect on salmon spawning habitat availability than would increases in mean annual flood magnitudes of up to 30%. We illustrate this result with an example from Staney Creek, a 16 ha catchment on Prince of Wales Island (Fig. 2a). In the absence of wood, only ~50% of stream reaches with slopes <4.5% had reach-average D_{50} suitable for salmonid spawning (Fig. 2b). Increasing mean annual flood magnitudes by up to 30% resulted in streambed coarsening of reach-average D_{50} (Fig. 2b), but this occurred primarily in reaches that were already predicted to be too coarse for salmon spawning. Consequently, little loss of salmon spawning gravel was predicted to result from streambed coarsening due to increased mean annual flood disturbance alone. The presence of wood was predicted to approximately double the extent of stream suitable for salmonid spawning in the Staney Creek catchment (Fig. 2a). Increasing mean annual flood magnitudes of up to 30% had negligible effects on streambed coarsening and had no effect on the basin-scale availability of salmon spawning gravel in the presence of wood.

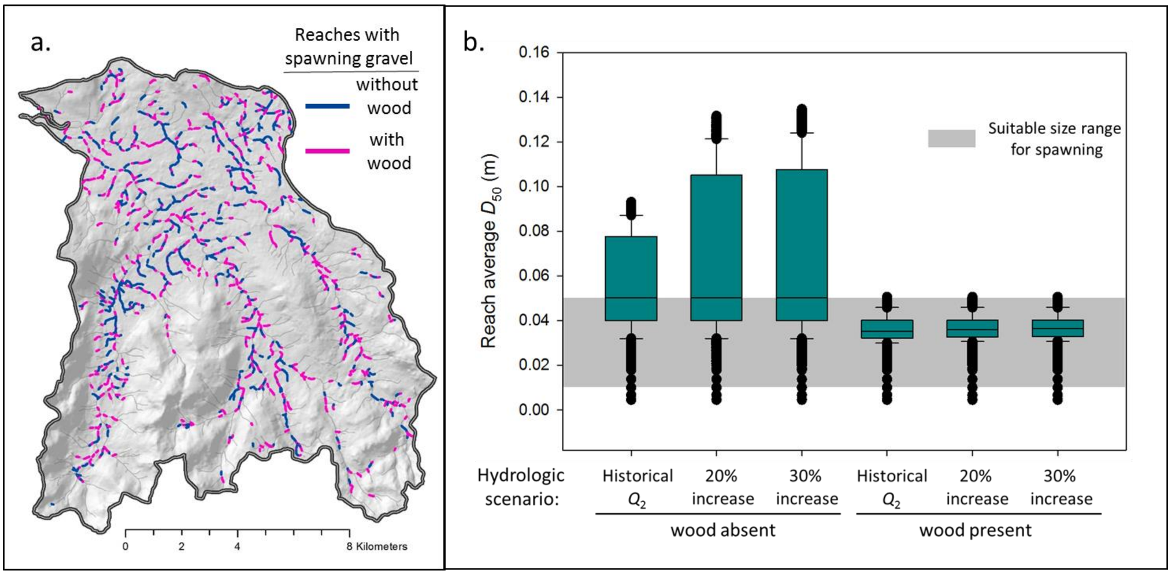

Figure 2: a. Map showing the predicted extent and distribution of salmon spawning gravel for Staney Creek, Prince of Wales Island, southeast Alaska. Blue reaches are predicted to have suitable spawning gravel without the influence of instream wood. Red bars are reaches that are predicted to require the hydraulic roughness created by wood to retain suitable spawning gravel. b. Reach-average D_{50} predictions for six combinations of mean annual flood magnitude and presence of instream wood in Staney Creek. Whiskers represent lines to data that are no more than 1.5 times the interquartile range. Top lines of boxes denote the 75th percentile, bottom lines the 25th percentile, and middle lines the means. Filled circles denote outliers. Grey area defines the range of suitable D_{50} values for salmon spawning.

Discussions and Conclusions

This work highlights the importance of wood for Pacific salmon spawning gravel availability in rivers draining TNF. Our simulations suggest that maintaining the processes that recruit wood to rivers, or actively restoring wood where those processes have been disrupted, is critical for maintaining salmon spawning gravel availability. In regions like southeast Alaska, where precipitation is expected to transition from snow to rain as a result of warmer winters, climate warming is expected to increase flood magnitudes. For TNF streams, mid-to-late century estimates suggest increases in mean annual flood magnitudes of ~30%. Our analysis suggests that increases on this order are unlikely to have substantial impacts to salmon spawning gravel availability, especially with the maintenance or restoration of wood in rivers. Our predictions should be viewed as first-order approximations that require field validation and empirical adjustment for local catchment conditions. However, our analysis provides a useful basin-scale perspective on the potential impact of wood loss (or benefit of wood restoration) for salmon spawning gravel availability relative to the effects of climate-induced changes in flood disturbance.

Acknowledgments: We thank Tongass National Forest personnel for generously providing data on stream channel morphology.

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Floating organic material along river corridors, and the potential impact of hydropower development

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Abstract

Floating organic material (FOM) is a key element along river corridors controlling geomorphic, biogeochemical, and ecological processes. This paper discusses the functional role of FOM as a hydro-geomorphological agent, dispersal vector for organisms, resource, as well as key habitat for plant and animal species. Quantitative data on FOM trapped by hydropower dams and reservoirs are presented for selected rivers in Europe, Russia, and the United States of America, and the expected implications for biodiversity are discussed. The paper provides the scientific basis to better understand the role of FOM in freshwaters for species richness as well as the potential consequences of hydropower dams on the dynamics and functions of FOM.

Keywords: *biodiversity, dispersal, river corridor, large wood, ecological integrity.*

Introduction

Rivers are linear ecosystems across landscapes that effectively transport sediments, organic material, and organisms. During increasing water levels, large amounts of coarse particulate material such as wood, leaves, fruits, as well as anthropogenic debris are mobilized and floating downstream. This floating organic material (FOM) represents an important albeit mostly neglected component along river corridors that functionally integrates upstream with downstream and riparian with instream areas (e.g. Gurnell et al., 2002). With fluctuating discharge, FOM undergoes distinct cycles of input, transport, deposition, and remobilization (Trottmann, 2004; Seo and Nakamura, 2009). During this cycle, it may serve as a dispersal vector, nutrient resource, habitat for both aquatic and terrestrial organisms, and geomorphologic agent.

River fragmentation by dams, however, alters the natural cycle of FOM and truncates its downstream transport. While the removal of very large size fractions of FOM is often necessary for the safe operation of dams and the protection of bankside infrastructure, it may have strong implications for the biodiversity along and the functional integrity of entire river corridors.

The aim of the present study was to review the existing literature about the functional role of FOM and to identify research gaps. In addition, we collected information on the amount of FOM trapped in a number of rivers and re-analysed preliminary data derived from a Swiss river, emphasizing the potential role of FOM for the mass dispersal of terrestrial organisms. In a second step, we evaluated the potential consequences of the future boom in global hydropower development (Zarfl et. al., 2015) on FOM dynamics. Based on these results, first recommendations on the sustainable management of FOM are provided.

Results and Discussion

The amount and the composition of FOM depend on the regional and local setting, the flow regime, and the riparian zone condition. Until most recently, research has mainly focused on drifting wood and floating woody debris (Gurnell et al., 2002), while information on other components of FOM is scarce.

We distinguish three key roles of FOM along river corridors. First, FOM serves as a hydro-geomorphological agent. Deposited along river margins woody debris has consequences on river style, channel avulsion, and sediment dynamics (Gurnell et. al., 2002). It may thus increase the lateral, vertical and longitudinal connectivity along river corridors and functionally connect the river with its floodplain (Tockner et. al, 2002). Deposition and accumulation of FOM may also increase the vertical exchange of water, nutrients and organic matter, thereby increasing nutrient retention and organic matter processing.

Second, FOM may contain very high densities of terrestrial invertebrates and serve as their long-distance dispersal vector, same as for seeds and plant propagules. About 50% of the terrestrial invertebrates are transported as eggs and juveniles (Boness, 1975). Along European rivers, the maximum distance of animals transported with FOM varied from 20 km to 300 km (Czogler & Rotarides, 1938; Trottmann, 2004). The distance depends on the properties of FOM (size, shape, density, and the ability of resprouting for deposited wood pieces), geomorphology of the river (e.g., mineral sediment caliber, geomorphologic style), and flow regime (Gurnell et. al., 2002).

Third, deposits of FOM provide suitable habitats and resources for local animal and plant assemblages in terms of moisture, shelter, nutrients, and organic matter. At the same time, it may serve as a refuge during harsh environmental conditions such as heat waves.

Barriers like dams, however, impede the downstream transport of FOM and alter its functional role. The quantitative data on volume of FOM extracted from reservoirs or observed floating on their surface in different rivers in Europe, Russia and the United States of America are presented in Table 1. Depending on watershed area, reservoir size and a number of local characteristics, volume of FOM could vary from hundreds to millions of cubic meters per year.

Table 1. Volume of FOM entrapped in hydropower reservoirs

Location of dam/reservoir	***Average amount of FOM extracted per year***	***Period of observation***	***Reference***
Hydropower dams on Rhine managed by EDF France	7 000 m^3	Reported in 2002	Le Lay and Moulin, 2007
Genissiat Dam, river Rhone (France)	5 321 m^3	1989 - 1999	Moulin and Piegay, 2004
Aare river, 13 hydropower dams (Switzerland)	21 500 m^3	1981 - 2003	Trottman, 2004
Zvornik hydropower reservoir, river Drina (Serbia)	2 508 m^3	2009	Zupanski, 2012
Bajina Basta hydropower reservoir, river Drina (Serbia)	12 140 m^3	2009 - 2011	Zupanski, 2012
Claytor Lake Hydroelectric Project, New River (Virginia, USA)	1 290 tonnes (≈3 300 m^3)	2003 - 2007	Kleinschmidt Energy and Water consultants, 2008
Housatonic Hydroelectric Project, Housatonic river (Connecticut, USA)	401.39 m^3	2006	Kleinschmidt Energy and Water consultants, 2008
Conowigo dam, Susquehanna River (Maryland, USA)	2 000 m^3	1989 - 1999	URS Corporation Gomez and Sullivan Engineers
	Floating wood		
Krasnoyarsk reservoir, Yenisei river	0.104 millions of m^3	1995	Korpachev, 2004
Sayano–Shushenskaya Dam, Yenisei	1.0 millions of m^3		
Bratsk Dam, Angara river	2.2 millions of m^3		
Ust-Ilimsk Dam, Angara river	0.9 millions of m^3		

The density of terrestrial invertebrates associated with FOM collected upstream of dams on the Aare river (Switzerland) between Lake Biel and descent to the Rhine river was up to 70 individuals per 100 g of dry material which is similar to the density reported from the mulch layer of forest soils per m^2 (0-0.2 m soil depth, Trottman, 2004). Considering densities of invertebrates per each taxonomic group (e.g. Diptera) for 100 L of FOM and the same volume of soil, they were found to be about two times higher for FOM. Linking the volume of FOM extracted from hydropower reservoirs (Table 1) with estimated densities of organisms indicates that around 800 million of living terrestrial invertebrates were removed from the ecosystem of Aare river and will not contribute to species diversity downstream.

Conclusion

FOM functionally links upstream with downstream river sections and aquatic with terrestrial ecosystems. The fragmentation of rivers by dams and the subsequent removal of FOM decrease habitat heterogeneity and reduce species and genetic diversity along river corridors. Information on the volume and composition of FOM is scarce and presented only in some case studies, which makes predictions of implications for other river basins more difficult. Detailed analysis of FOM dynamics and its functional role should be conducted in a systematic way in order to develop a conceptual model that allows understanding and forecasting the impact of future hydropower development on environmental heterogeneity along river corridors. This will provide a scientific basis for river management actions aimed at reasonable reintroduction of FOM downstream.

Acknowledgments

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Reintroduction of large wood in navigable rivers: a pilot study to stimulate biodiversity within safety constraints

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Abstract

Large wood in the form of dead trees has been introduced into the navigable river Rhine as a pilot measure to improve the aquatic biodiversity. Within the same year characteristic riverine macro invertebrate species returned and fish community profited from the under water structure.

Keywords: *large wood; navigation; biodiversity; macro-invertebrates, fish.*

Introduction

River ecosystems in the Netherlands lost much of their specific values due to human impact. An important change in these controlled river systems is the lack of large wood in the main channel and tributaries. Since riparian forests have become rare and large wood is actively removed from the water, this natural structure is nowadays missing in our large rivers. Studies indicate that large wood is an important habitat structure for both fish and macro-invertebrates (Piégay & Gurnell, 1997). Large wood also enhances morphological differentiation of the river bed in free flowing rivers (Gurnell et al., 1995, Gerhard & Reich 2000). The reintroduction of large wood has proved to be a successful measure in many smaller river systems worldwide (e.g. Kail et al., 2007; Miller et al., 2010). In the larger rivers, with shipping as an important economic function however, large wood has never been applied. Therefore, in December 2013, Rijkswaterstaat started a pilot study to investigate the contribution of large wood in navigable rivers to better achieve the goals of the Water Framework Directive (WFD).

Figure 1: Location of the study area along the Rhine river in the Netherlands. Green dots=pilot locations, red line=weirs.

Pilot study

The pilot study was carried out at four locations in the river Nederrijn-Lek, a branch of the river Rhine (Fig. 1). This stretch of river is impounded and therefore any possible maximum effect of large wood will be reduced, but it was selected for safety reasons: navigation is less intensive as in the free flowing branches Waal and IJssel. In order to investigate the steering parameters of large wood, we selected study sites that differed in water depth, stream dynamics and exposure (main channel vs. side waters).

A primary condition in these experiments is that the trees that were used as large wood stay in position, even during high flood periods. Large wood drifting in the fairway can lead to dangerous situations which must be prevented. Determining the appropriate fixing method is therefore an important part of this pilot study. A total of nine trees (length ~15 metres), including branches and roots, were placed just under the water surface near the banks of the river in the main channel (Fig. 2a), a side channel and a fishway. The trees were attached to steel beams by strong steel chains. Another six trees were placed behind groynes, in deep erosion pits or at sufficient distance from the navigation channel. (Fig. 3). These trees were attached to two large concrete slabs of over 2,000 kg (Fig. 2b). With this, we created sites with large wood that differences in light intensity and stream velocity.

Figure 2: a) Trees are placed in shallow zones along the river

b) Trees weighted with concrete slabs are placed in erosion pits behind groynes, up to 9 meters deep.

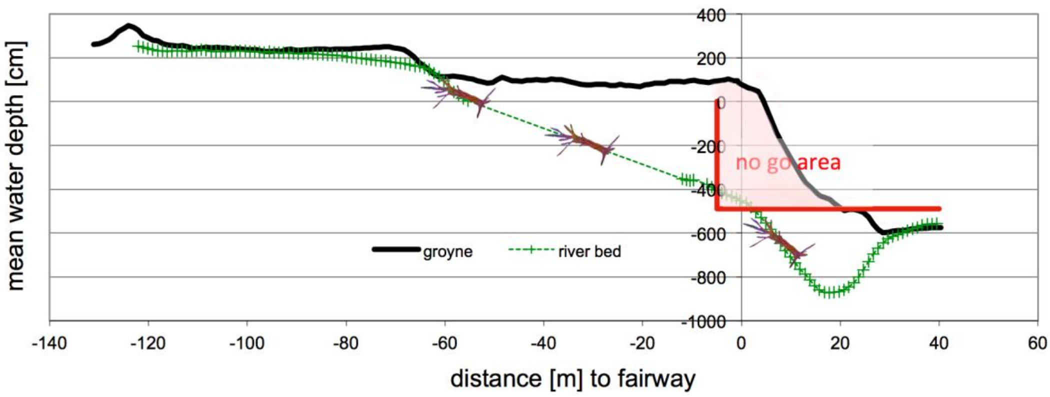

Figure 3: Trees are placed behind groynes, in deep erosion pits or at sufficient distance from the navigation channel.

Ecological effects

The main goal of reintroducing large wood into the river system was to enhance ecological diversity, especially for fish and macro-invertebrates. Accordingly, monitoring concentrated on these taxa. Fish surveys based on fyke nets and electrofishing complemented with underwater video surveys, provided insights into the presence of fish in the large wood structures. On the shallow locations, especially near the branches, high concentrations of juvenile fish were found (Fig. 4a). The fish community in the groyne fields is dominated by the alien Round goby (*Neogobius melanostomus*). The fish community around the trees is composed more evenly, and consists of many more native species, whereby biodiversity is higher. Fish use the trees to shelter and to eat. There are also strong indications that they use the dead trees as a spawning area.

For the macro-invertebrate sampling different methods have been utilized. One entire tree was sampled by lifting it from the fishway and washing it, but also less drastic sampling methods by subsampling were tested. On the dead trees, high numbers of characteristic riverine species are found, such as caddisflies (*Trichoptera*) and Chironomidae (*Diptera*), which are missing on the studied rip-rap in the river. The preliminary results of this first year of monitoring (spring and autumn) indicate that the first phase of colonization is prosperous (Fig. 4b). We now follow this process for at least another 2 year, to find out if the native fauna on the dead trees persists, despite the pressure from dominant alien invaders.

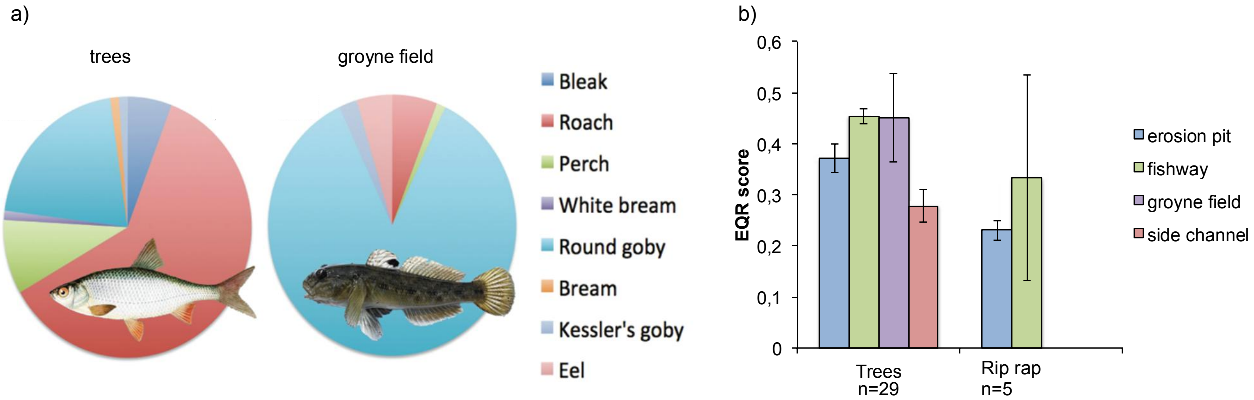

Figure 4: a)The fish community near the dead trees differs from the reference site in sandy groyne fields (relative densities electrofishing) b) EQR score of macro invertebrates compared in different locations on trees and rip rap. (EQR scores with 95% confidence intervals)

Future

If future monitoring confirm these results and the large wood contribution to biodiversity persists ánd the fixation methods prove to be adequate, the measure will be exported to more and faster flowing parts of rivers. In those circumstances, we expect even more interesting results, with large wood not only providing habitat structure, but also generating habitat diversity by enhancing and changing morphodynamic processes such as erosion and sedimentation. In this way the river system can be interlaced with small hot spots of high ecological diversity, in co-existence with shipping and flood-defence structures.

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Effects of single wood logs on surrounding patterns of flow, sediments and benthic invertebrate communities in a lowland river

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Abstract

Tree trunks that naturally fall into rivers or are introduced through river restoration have been shown to significantly change the flow and sediment characteristics in the surrounding areas of the river bed. Hence, we hypothesized that even the presence of a single wood log may exert significant and reproducible effects on invertebrate colonization in its surroundings.

Therefore, we systematically analysed the effects of simple large wood (LW) structures, as four single wood logs (designed as replicates), on flow, sediment properties and invertebrate communities in the river channel areas around them (from 60 cm upstream to 160 cm downstream of the LW). Results were compared with those obtained in four control sites in the same river but without the presence of LW.

Surveys revealed that LW logs typically triggered the formation of three distinct habitat patches which were: scouring pools with gravel; sand bars; and accumulations of organic matter. These habitat patches consistently exhibited distinct combinations of physical conditions (i.e. flow patterns, sediment composition and organic content), and were also colonized by distinctive invertebrate communities. Invertebrate communities showed higher levels of taxonomic diversity (+ 168 %) as well as functional diversity (+ 173 %) across all these habitat patches in comparison to the control sites.

Our study shows that the presence of LW triggers increased heterogeneity of flow and sediment composition, which is then linked to higher invertebrate diversity. Thus, even simple structures of large wood can cause a cascade of abiotic and biotic effects in a lowland river system.

Keywords: *Large wood; benthic habitat; biodiversity; habitat heterogeneity.*

Introduction

Several studies have demonstrated that the presence of large wood (LW) in streams and rivers represents an important hydraulic roughness element which can significantly modify the hydromorphology of channels, for example changing water depth and flow velocity profiles, erosion and deposition processes, and the distribution and retention of inorganic and organic sediments (see for example Gurnell et al., 2002; Montgomery et al., 2003).

LW also represents a unique hard and stable substratum for colonization by invertebrates, which provides trophic resources, flow refugia, shelter against predation and attachment options (see for example Benke and Wallce, 2003; Hoffmann and Hering, 2000). As a consequence, the surface of LW is widely recognized as a hotspot of invertebrate diversity in river systems.

Only a few studies (Gerhard and Reich, 2000; Hilderbrand et al., 1997; Wallace et al., 1995), however, have investigated the potential effects of LW on benthic communities colonizing the nearby riverbed sediments. In particular, less is known about the effects of simple LW structures, as single wood logs, on the physical conditions and benthic fauna colonization in surrounding riverbed sediments in sandy lowland rivers.

Therefore, this study aimed to quantify the effects of single LW logs on the structural and functional composition of benthic invertebrate communities in the surrounding riverbed sediments and to relate those effects to the hydromorphological changes induced by the LW.

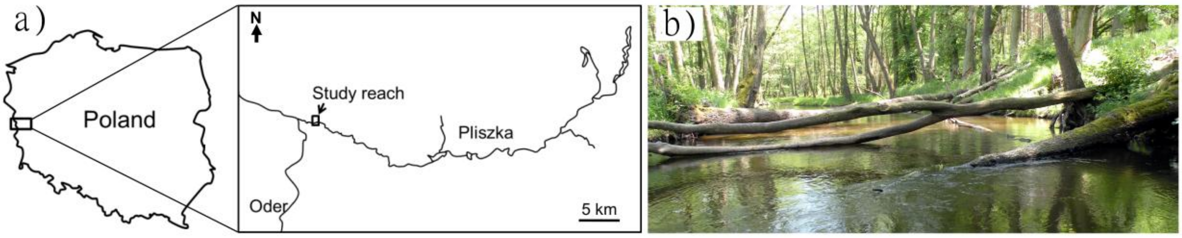

Figure 1: Map of the study area (a), from Pilotto et al. (2014). Picture of large wood in the Piszka River (b).

Study Area

This study was carried out along a 100-m-long study reach (52°14’58’’N,14°44’18’’E) of the Pliszka River, a low gradient, sand-dominated tributary to the Oder River (western Poland). The study reach (mean channel width: 9.55 m, mean water depth: 0.58 m, discharge: 1.82 m^3s^{-1}) was characterized by forested banks (mainly alder [*Alnus glutinosa*]) and abundant in-channel LW (19 LW logs in 100 m, length: 1.29-13.60 m, diameter: 12-40 cm). Due to the limited stream power, nearly all LW logs falling into the channel remain in place as single logs, mostly aligned across the channel perpendicular to the flow direction.

Materials and Methods

Field work was carried out in November 2012. Four single pieces of LW (diameter: 22-40 cm, length: 6.20-13.60 m, distance to the next LW: >5 m), with approximately perpendicular orientation to river flow, and partially embedded in the riverbed sediment, were selected within the study reach as replicates.

Sediment composition around the LW logs was visually classified as: coarse sand and fine gravel (‘gravel’); sand bars and shifting sand (‘sand’); and accumulations of fine and coarse particulate organic matter (‘organic matter’). For each of the three patches we set five transects of sampling sites located 160, 60 and 10 cm downstream and at 10 and 60 cm upstream of the LW. At each sampling site, data on flow velocity, sediment properties and invertebrate colonization were gathered (for details see Pilotto et al., 2014). This sampling grid was repeated for all four replicate logs. Invertebrate samples and flow measurements were also taken from the surface of the LW logs (3 samples per LW). Additionally, measurements of flow velocity, sediment properties and invertebrate colonization were taken from four ‘control‘ sites. These were set randomly in the upstream part of the reach, outside the direct influence of LW (distance to the next LW > 10 m).

Results

Mean flow velocity, sediment sorting index and water depth significantly differed among the substratum patches (linear mixed effect models, LME, $p<0.01$), and their variances were 170, 1000 and 25 times larger respectively in channel areas surrounding the LW than in the control area.

The different substratum patches (LW, gravel, sand and organic matter) were colonized by distinct invertebrate communities (ANOSIM, $p< 0.01$). The taxonomic composition of the control samples was statistically different from all other groups of samples (ANOSIM, $p<0.05$), with the exception of sand (ANOSIM, $p=0.06$). Invertebrate communities from the riverbed sediments around the LW were all characterized by significantly higher values of taxonomic diversity (Shannon-Wiener diversity index) than the control samples (Kruskal-Wallis test, $p<0.05$), and showed similar diversity values to the LW surface. Overall, taxonomic diversity was 168 % higher in the LW areas than in the controls. Such increase in taxonomic diversity was paralleled by a 173% overall increase in invertebrate functional diversity.

Discussions and Conclusions

Our results demonstrated that in this river the presence of LW was associated with the formation of three additional habitats with distinct physical conditions and macroinvertebrate communities. These habitats comprised: (i) the LW log itself; (ii) scouring pools with coarser sediment and greater water depths, flow velocities and turbulence (gravel patch); and (iii) sheltered areas with lower flow velocities and sediments rich in organic matter.

The invertebrate communities colonizing the habitats surrounding the LW logs showed high values of taxonomic and functional diversity, which were associated with the increased diversification of habitat properties. Such heterogeneous environments that form around the LW enable a large number of ecological niches for invertebrates and favour short-distance dispersal compared to more homogeneous environments (Beisel et al., 2000). The invertebrate diversity in the river sediments surrounding the LW was similar to that recorded on the LW itself, which is a well known hotspot of invertebrate diversity (Benke and Wallace, 2003; Hoffmann and Hering, 2000). Thus, LW not only represents a hotspot for invertebrate diversity itself, but additionally induces the formation of heterogeneous habitats in its surroundings which also promotes diverse invertebrate communities.

Hence, the presence of even simple structures of LW in a lowland river system triggers increased heterogeneity of flow and sediment composition, which is then linked to higher invertebrate diversity through a cascade of abiotic and biotic effects. Thus, the ecological role of large wood in rivers is potentially even more important than hitherto recognized and LW should be retained through conservation programmes or introduced through river restoration activities wherever possible.

Acknowledgments

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Disentangling the driving variables of vegetated landforms in a braided-wandering alluvial forest

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Abstract

Vegetation and riverine processes have been increasingly recognized as interacting dynamically, influencing the development of fluvial landforms and eventually the overall river planform morphology. Recently this has led to the notion of the biogeomorphic succession. This theoretical framework proposes the initial geomorphic dependence of young fluvial landforms (fresh bars) and, through a biogeomorphic transition, ends with an ecological phase, where ecological processes are predominant (e.g. fluvial terraces, with an ecosystem largely decoupled from the active fluvial system). However, evolution of relationships between environmental variables through the biogeomorphic succession trajectory have not yet been demonstrated.

This paper quantifies the evolution of the relationship between plant development and riverine processes using advanced dendrochronological and dendroecological methods. We hypothesise that fluvial influence is dominant at the beginning of the biogeomorphic succession but that there is a transition to climatic dependence by the ecological phase, as the forest ecosystem becomes more developed. We test this hypothesis for a braided-wandering river system in Switzerland (Allondon River). A multivariate dendroecological approach allows identification of when this transition occurs, and how it relates to wider landform development, and so the time scales associated with biogeomorphic succession.

Keywords: *braided rivers;* dendroecological*; biogeomorphic succession*.

Medium- and short-term vegetation cover and channel dynamics in the Piave River

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Abstract

Many gravel bed rivers in the European area suffered different ranges and types of human pressure that modified their vegetation cover and morphology. This work presents the case of a 13 km-long study reach located into the foothill portion of the Piave River. The timing and extent of the fluvial vegetation dynamic and the active channel changes that occurred over the last 30 years, were carried out. The Piave river is historically influenced by human activities such as bank protection, gravel mining, hydropower schemes and water diversion. Large areas of the former active channel have been colonized by riparian vegetation, both as islands and as marginal woodlands. Assessing the type and dynamics of islands in a riverine system can help to depict processes of woods recruitment, river changes and temporal evolution. The medium-term (1982-2011) and short-term (2010-2011) morphological changes have been analyzed trough photointerpretation of aerial photos, hydrological data analysis and published works review. During the medium-term interval, the alteration of the sediment regime has determined a trend, up to 1991, of fluvial island increasing and active channel narrowing. After this period, a reduction of vegetated area and an expansion of the active area were subsequent to significant flood events. The analysis has also allowed to assess the morphological effect of two flood events. Near bankfull floods seems able to produce significant fluvial islands erosion.

Keywords: riparian vegetation; woods recruitment; planform changes; human impact; floods; Piave river.

Introduction

Over the last 200 years the most Italian and European rivers have suffered considerable human pressures both at the basin and channel scales (Gurnell et al., 2009; Comiti et al., 2011, Surian *et al.*, 2014). Deforestation and reforestation phases, channelizations, gravel mining, urbanization, dam building, torrent-control works, water diversions , hydro-electric power generation, and many other interventions have strongly affected many fluvial ecosystems (Moretto et al., 2013a). Sediment transport can be reduced up to 50% due by dam, bank protection and control structures (Liébault and Piégay, 2001; Globevnik and Mikoš, 2009). Deficit of sediment supply in many Italian rivers was increased by in-channel mining, especially between 1960 and 1980 (Comiti et al., 2011). This work assess the morphological evolution and the associated islands dynamics a study reach of the foothill course of the Piave River, over the last 30 years. The aims of this paper are: (i) to analyze the medium term (1982-2011) dynamic of the fluvial island and the active channel area to focus on the potential woods recruitment; (ii) to analyze the short term effect of two near bankfull flood events occurred between November and December 2010.

Study Area

The study reach is about 13 km long and it is located into the foothill course of the Piave River (North-East of

Italy) between Ponte nelle Alpi and Praloran. The morphology of the river in the study reach is dominated by braided and wandering channel patterns (Comiti *et al*., 2011). The slope is (on average) 0.45%, and the median surface grain size ranges between 20 and 50 mm (Comiti *et al*., 2011). The geology of the riverbed is sedimentary predominant (Comiti *et al*., 2011). The average annual precipitation is equal to 1350 mm and the hydrological regime has a bimodal pattern of floods that is in spring (mainly due on snowmelt) and autumn (Comiti *et al*., 2011). The largest, flood event was recorded in 1966 and reached almost 4000 $m^3 s^{-1}$, whereas “bankfull” discharge (RI=2 years) was identified to be ~700 $m^3 s^{-1}$ (Comiti *et al*., 2011). A flow regulation capacity, from dams, in the upper basin its present from the 1950 that shows a reduction of peak discharge in the post-regulation period (Da Canal, 2006).

Materials and Methods

The evolution of islands and morphologies over the last 30 years were analyzed taking advantage of the work of Comiti *et al.,* 2011 and extended with two series of aerial photos (2010 and 2011), acquired during low-flow conditions. Aerial photographs were rectified and co-registered to a common datum base at 1:5000 using a GIS software (ESRI® ArcGIS 10). Approximately 40 ground-control points were used to rectify each single frame, and third-order polynomial transformations were then applied, obtaining root mean square errors (RMSE) ranging from 0.3 to 1 m.

These photos were analyzed using the same method described in Moretto *et al.* (2013), in order to identify the active channel and islands extents along the whole 13 km-long study reach. The active channel is defined as the area without shrub vegetation, thus including un-vegetated bars and active and inactive channels, while the fluvial islands class include pioneer, young and stable islands according to Gurnell and Petts (2002) classification.

Results

The analysis of the extent of the fluvial island and the active channel carried out using the 2010 and 2011 aerial photos revealed significant changes. During this period were recorded two main floods of about 498 m^3/s and 404 m^3/s, respectively (Figure 1).

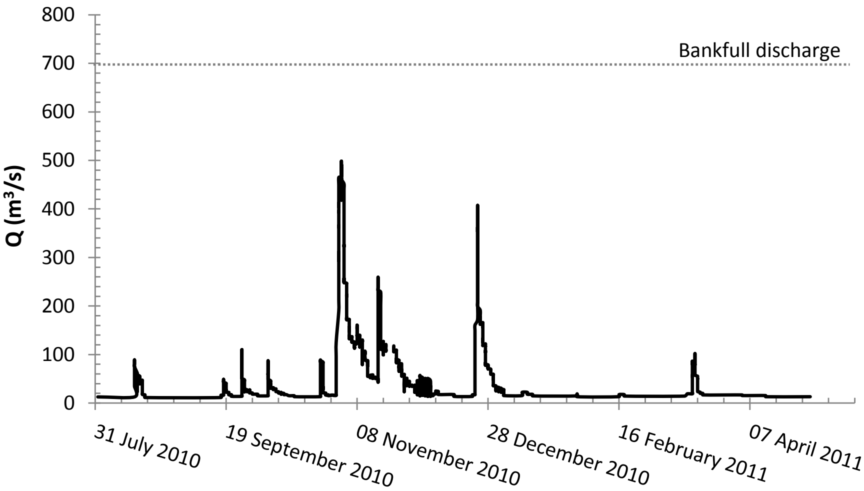

Figure 1: Hydrograph of 2010 floods (average hourly discharges as measured at the Soverzene gauging station) of Piave River.

Changes in fluvial islands were characterized by a decrease of around 57.7 ha, equal to a recruitment of the 63.2 % of the total area of in-channel woods patch (Table 1). On the other hand, the exposed gravels area were characterized by an increase of about 46 ha (+ 19.3 %).

Table 1: Fluvial island and exposed gravel extent derived by photointerpretation of the 2010 and 2011 aerial photos.

		Year		**2011 - 2010**	
		2010	2011	(ha)	(%)
Fluvial Islands	(ha)	92.9	34.2	-58.7	-63.2
Exposed gravel area	(ha)	238.7	284.7	46.0	19.3
TOTAL Active Channel	(ha)	331.6	318.9	-12.7	-3.8

Discussions and Conclusions

The Piave River during 20° century showed a general reduction in channel width up to 1991 due to the predominant effect of human activities (Comiti *et al*., 2011). From 1991, phases of active channel expansion and islands reduction (woods recruitment) in correspondence of the principal flood events (1993 and 2002 with R.I. > 10 years) were registered. Therefore from 1991 the river dynamic, in term of active channel and island fluctuation, seems more related with flood activities. Thanks to the photointerpretation of 2010 and 2011 were registered a significant loss of fluvial island (Table 1) related with two flood events lower than bankfull level. Similar results were founded by Delai *et al*., 2014 (in the same river) and Moretto *et al*., 2013b (in the Tagliamento River) in terms of sediment eroded and deposited.

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Large wood-induced storage of sediment and organic carbon in mountainous streams of the Colorado Rocky Mountains, U.S.A.

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Abstract

We quantify organic carbon storage in large downed wood on floodplains and in channels along 37 mountainous headwater stream segments of the Colorado Rocky Mountains, USA. We stratify sampling sites based on forest stand age, valley confinement, and channel planform including multithread channels, which occur only in unconfined valley segments with old-growth forests. Comparison between 11 paired study reaches indicates that multithread channels in unconfined valley segments store 4 times more organic carbon as downed wood per valley length (instream and floodplain) than single thread channels in more confined valley segments. Additional analysis (i) will quantify differences in organic carbon storage across valley type, channel planform, and stand age along all 37 reaches and (ii) examine relationships between logjam spacing and floodplain sediment volumes estimated from field measurements of floodplain soil depth. These results have important implications for land-use management including wood removal from streams and channelization as well as factors that influence stand age (e.g., deforestation, wildfire, insect infestation). Loss of wood recruitment in streams prevents the development of multithread channels and retention of sediment and organic carbon important for ecosystem processing and potential long-term carbon storage in headwater streams of the Colorado Front Range.

Keywords: streams; carbon; wood; valley confinement; floodplain

Introduction

Rivers are becoming increasingly emphasized as important components of the terrestrial carbon cycle (Aufdenkampe et al., 2011; Hoffmann et al., 2013). Researchers have estimated allochthonous organic carbon (OC) fluxes into headwater streams, autochthonous primary production in rivers and the eventual liberation through outgassing by aquatic biota to the atmosphere or delivery to the ocean (Aufdenkampe et al., 2011; Battin et al., 2009, 2008). Terrestrial carbon (C) fluxes account for the most uncertainty in the global carbon budget and accounting for growing terrestrial carbon sinks has proven to be difficult (Ballantyne et al., 2012). It has been suggested that C is stored within the geosphere somewhere along the fluvial journey to the atmosphere or oceans (Aufdenkampe et al., 2011) and that this could be part of the unaccounted C in global budgets (Hoffmann et al., 2013). Studies examining the mechanistic influences of C storage in rivers is limited (Wohl et al., 2012), but studies show that downed instream and floodplain wood can be a significant component of carbon storage and source of particulate organic matter in streams (Ward and Aumen, 1986; Wohl et al., 2012; Beckman and Wohl, 2014). Our ongoing work shows that wood in rivers serves as a significant reservoir for C and is partly responsible for morphodynamics that facilitate OC retention behind log jams and on floodplains in relatively undisturbed mountainous headwater streams of the Colorado Front Range, U.S (Polvi and Wohl, 2013; Wohl, 2013; Beckman and Wohl, 2014).

Study Area

Rocky Mountain National Park (RMNP) in Colorado, USA is an ideal place to examine wood in rivers because it has experienced limited anthropogenic disturbance and well-documented land-use and land-cover history, including old-growth forest stands (>200 yr). Geologic controls provide diverse degrees of valley confinement and channel planform. Abundant instream wood creates numerous log-jams that function as obstructions to flow, promote floodplain connectivity, encourage channel avulsion, and facilitate storage of organic matter. In old-growth forests the trees are large enough to create persistent channel-spanning logjams, which facilitate overbank flow and can result in the development of multiple channels of flow across valley bottoms (referred to as multithread channels).

Materials and Methods

Large downed floodplain and instream wood was surveyed at 37 study sites in RMNP and surrounding areas. Study reaches are stratified based on the degree of valley confinement and forest stand age. We define valley confinement as: 1) confined, exhibiting a valley bottom width (w_v) < 2 times the bankfull channel average width (w_c); 2) partly confined ($2w_c < w_v < 6w_c$); and 3) unconfined ($w_v > 6w_c$). Large downed wood pieces greater than 1 m in length and greater than 10 cm in diameter were surveyed. Wood volumes were converted into mass of wood using average wood density documented in the area (400 kg/m^3(Ross and USDA Forest Service, 2010; Veblen and Donnegan, 2005). Conversion to mass of OC was conducted assuming 50% of OC by mass. Eleven paired study sites were examined for relative comparison of OC stocks between instream and floodplain reservoirs across valley type. Additional analysis will include examination of relationships between valley width, logjam spacing, volume of floodplain sediment, occurrence of multithread channels, and total megagrams of OC per 100-m valley length (Mg C 100-m) for the three valley types and forest stand age.

Results

Results from 11 paired study sites indicate that unconfined valley segments store a disproportionate amount of wood and OC in streams and on floodplains compared to more confined and partly confined valley segments in the study area (Fig 1). Multithread channel segments store 4 times the wood and OC content compared to more confined single-thread channels. The large majority of wood and associated OC is stored on the floodplain compared to the channel. Regression between instream and floodplain OC per valley length as wood indicates a significant relationship (r^2=0.59). Additional analysis will examine the potential influence of logjam spacing on floodplain sediment volumes, and quantify differences between the four valley types in younger and old-growth forests.

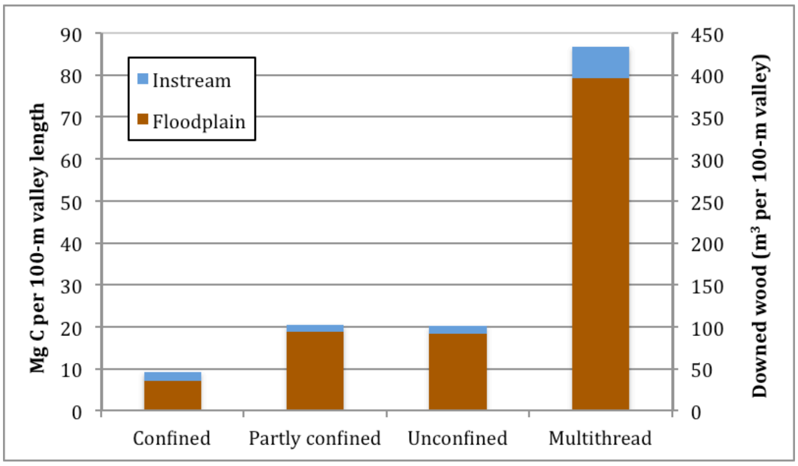

Figure 1. Mean organic carbon storage as floodplain and instream wood at 11 paired study sites in confined, partly confined, and unconfined valley segments with single thread streams and multithread channels. Multithread channels occur only where old-growth forests are present and store much more organic carbon per valley length compared to single thread channels in more confined valley segments.

Discussions and Conclusions

Large downed wood in streams and on the floodplain of mountainous headwater streams are significant components of OC storage in the Colorado Front Range. Logjams in multithread channels of unconfined valley segments with old-growth forests facilitate complex feedbacks that ensure continued wood recruitment to the channel and on the floodplain. Multithread channel segments associated with logjams in old-growth forests of the study area have been shown to store more OC per area as wood, whereas beaver meadows have been shown to store more OC in floodplain sediment (Wohl et al., 2012). Potential relationships between logjam spacing in unconfined multithread channels have implications for increased sediment storage and abundant OC retention in soils as well as downed wood. Preliminary findings presented here emphasize the importance of old-growth forests on long-term terrestrial carbon storage with implications for land use and climate change. Increases in the severity and frequency of wildfire and beetle infestation, such as those projected in North America (Bentz et al., 2010; Westerling et al., 2006), as well as rapid deforestation, may (i) limit stand age, (ii) hinder development of multithread channels, and (iii) alter natural processes that retain OC in mountainous headwater streams.

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Channel Incision and Floodplain Abandonment Due to Historic Wood Removal in Washington State, USA

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Keywords: *Channel incision; wood; floodplain connectivity; terrace formation, fluvial geomorphology.*

Introduction

Historic Channel incision can result in extensive ecological consequences such as disconnecting floodplains, lowering groundwater tables, increasing downstream sedimentation, and elevating downstream flood peaks. Incision often results in expensive impacts to infrastructure such as bridges, buried pipeline crossings, water intakes and road embankments. The process also setups long-term geomorphic adjustments as the channel network adjusts to a new base level. Channel incision is a common response to human actions that diminish sediment supply or increase discharge and reduce natural roughness to increase sediment transport capacity. This typically occurs downstream of dams that trap sediment, in catchments where development has increased peak flows, or where rivers have been shortened and constrained by levees. Although clearing wood from channels has been recognized as a trigger for channel incision (Veatch 1906, Guardia 1933, Montgomery et al.1996, Stock et al. 2005), the scale to which it can impact drainage networks isn't reflected in the literature. This study examines a relatively undeveloped watershed with no dams that has experienced greater than 3 meters of incision over the last century due to solely to the removal of wood and riparian forests. The incision occurred despite an increase in sediment supply resulting from Intensive industrial logging, demonstrating the importance of in-stream wood on partitioning shear stress and trapping sediment.

This study assessed the geomorphic evolution of the South Fork during the historic record (1930's to present) in response to logging and wood removal, and the resultant degraded habitat conditions for salmonids. Historic air photos and recent LiDAR (light-activated radar) topography collected in 2013 were used to evaluate the timing and magnitude of incision in the South Fork. Based on these findings, and accounts of historic conditions, a conceptual model of channel evolution was developed that describes the geomorphic history and loss of salmonid habitat in the South Fork.

Study Area

The South Fork Nooksack River is located in Whatcom County, northwestern Washington State, USA. The river originates in the Twin Sisters Range, part of the larger Cascade Mountains Range extending from British Columbia to northern California. The project reach is located between river kilometer (RK) 10.6 and 19.3 where the valley bottom is typically 2000 meters wide and the reach average slope is 0.32%. The dominant substrate types in the reach range from coarse gravel to cobble, with pockets of finer sand and gravels. The channel is characterized by a broad meandering pool-riffle morphology and large gravel point bars bisected with chute channels that are inundated during bankfull flows but dry most of the year.

Historic logging of mature riparian forests and direct removal of instream wood in the South Fork Nooksack River in northwestern Washington State, USA, has lead to dramatic channel incision and loss of off-channel habitats for endangered salmonids. Under pre-European settlement conditions, the river was a forced anabranching channel dominated by numerous large logjams that once spanned the entire channel width. A mature riparian forest dominated by large trees covered the entire valley bottom, providing a source of large wood to the system. Once recruited into the channel, these large trees forced and maintained flow splits, creating an anabranching channel planform with numerous pools that was hydrologically connected to the adjacent floodplain and side channels. Salmonid populations thrived in the diverse habitats formed within this dynamic landscape. Logging of the forest floor and removal of wood from the channel in the early 20th century initiated dramatic changes in the river's morphology and ecology..

Materials and Methods

Historic air photos and topographic data was collected in 2013, and surveyed channel cross sections were used to evaluate the timing and magnitude of incision in the South Fork. The locations of historic channel were digitized for each of the historic aerial photos available in GIS. A terrain analysis was performed using the LiDAR data to establish floodplain elevations relative to the current channel, using methods adapted from Jones (2006). The resultant relative elevation map (REM) and historic channel alignments were used to evaluate historic channel incision by comparing the relative elevation of historic channel to the current channel. Cross sections were extracted from the LiDAR and the most recent active channel occupying each portion of the cross section were combined to evaluate the relative position of historic channel. This method allows characterization in both horizontal (lateral bank erosion and avulsions) and vertical (aggradation and incision) changes over time. Overbank floodplain sedimentation and instream bar development are not accounted for, thus maximum incision rates are calculated using this method.

Results

At the lower end of the project (RK 16.9) there is about 3.1 m of relief in historic alluvial surfaces with consistent incision through the 93-year record of 0.03 m/yr (Figure 1). At RM 10.9 the 1885 channel surface was identified, providing a 126-year record over which there has also been 2.8 m of incision averaging about 0.02 m/yr (Figure 1). At RK 18.2 only the 17 years of record (1994-2011) could be used due to channel migration reoccupying previous channels. Total relief is 0.8 m over the record, showing a higher incision rate (0.04 m/yr) in the last 10-20 years (Figure 1). The previous sites downstream (RK 16.9 and 17.6) also show higher incision rates of 0.1 m/yr in recent decades (Figure 1). In 1943 the upstream most cross section at RK 18.8 was 1.5 m above its position in 2011, translating into an incision rate of 0.02 m/yr.). A similar analysis 15 km upstream also documented three meters of incision, however the timing was delayed relative to this downstream project reach, indicating the incision propagated upstream on average 0.5 km/yr.

Prior to European colonization in the 1800s, the river would have naturally experienced variable sediment and wood loading as the channel locally eroded banks and islands. This local erosion would have introduced sediment and large wood into the river, creating stable logjams and deflecting flows away from the eroding bank. The general trend would have been aggradation interrupted by periods of local incision (Abbe et al. 2003, Montgomery and Abbe 2006). Over the long-term, the system would reach an equilibrium grade where aggradation and erosion maintained a relatively constant grade. The variability introduced by stable wood would define how "dynamic" that equilibrium would be. Incision resulting from wood removal can quickly cut through alluvium into underlying bedrock, not only impacting river ecology but altering landscape evolution (Montgomery et al. 1996, Stock et al. 2005).

Discussions and Conclusions

The clearing of logjams and logging of riparian forests destabilized the South Fork Nooksack River by removing the backbone of the system. Similar to other forest rivers, large trees played a critical role in controlling the river's grade and planform (Wolff 1916, Abbe and Montgomery 2003, Brummer et al. 2006, Collins et al. 2012). More than three meters of incision that has occurred as a result of wood removal that has degraded habitat conditions by increasing average substrate size (impacting spawning), reducing groundwater levels (decreasing hyporheic exchange, limiting floodplain vegetation maturity), and disconnecting the adjacent floodplain and side channels (rearing and spawning habitats). Analysis has demonstrated that incision has propagated up the river valley and is thus impacting much of the tributary channel network. This assessment demonstrates that removing the large trees from rivers and their riparian areas has large scale impacts to landscape evolution, ecology and human infrastructure.

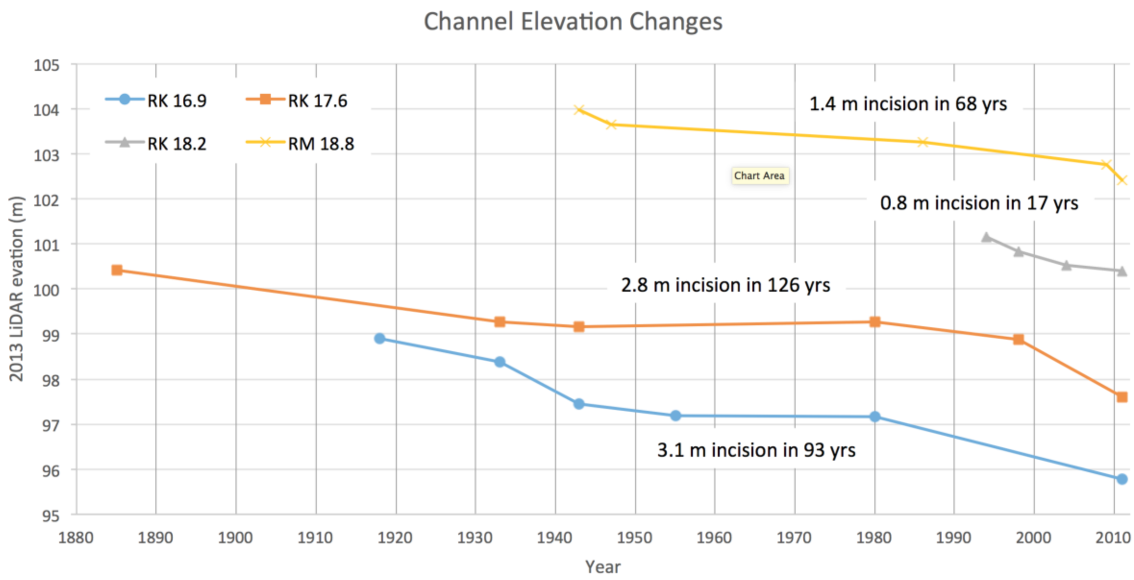

Figure 1:

Topographic elevation of historic channels over time at 4 locations along the project reach. Total lowering of the channel (incision) and length of record provided at each cross section assessed.

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Driftcretions: Driftwood and its legacy on the shoreline morphology of a large subarctic lake.

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Abstract

We use the Great Slave Lake as a natural wood-rich laboratory to study the morphological impacts of high wood loads along shorelines, rates of landscape change, and the legacy of driftwood over long time scales. We introduce the term driftcretion to describe large concentrations of driftwood that promote sedimentation and interact with vegetation to influence shoreline morphology. Driftcretions are not transitory landscape elements but are permanent and impact landscape appearance. For example, after 8000 years of wood delivery at the Great Slave Lake, driftcretions have impacted the morphology of the shorelines up to ~6 km inland. This has created a complex, mosaicked landscape with diverse habitats and increased potential for carbon capture in offshore standing water bodies. Most instream wood research has focused on zones of wood production or zones of wood transfer rather than zones of wood deposition. This study shows that driftwood in deposition zones can have profound impacts on the landscape and we encourage more wood researchers to begin to work in these areas.

Keywords: *lake, driftwood, landscape evolution, shoreline morphology, large wood, subarctic.*

Introduction

Driftwood greatly facilitates biogeomorphic plant succession in a dynamic high disturbance setting: the interface between land and water. In landscapes with high amounts of driftwood, these interactions lead to major alteration of physical and ecological states. For example, high wood loads are shown to play a major role in maintaining: step-pool and multi-thread channels in low gradient mountain alluvial valleys (Polvi and Wohl, 2013), vegetated island-braided rivers (Gurnell and Petts, 2002), large expanses of alluvial old growth forests on floodplains (Collins et al., 2002), semi-stable multi-thread wide distributary channels in deltas (Phillips, 2012) and habitat patchiness and bio-availability of nutrients in coastal and mi-ocean environments (Gonor et al., 1988). Without driftwood these landscapes revert to a simpler design that supports less life.

Driftwood also plays a major role distributing water-born nutrients and organic particulates, including carbon, into broader areas than would otherwise be readily available. Research that investigates the long term storage and decay of drift piles and its legacy impact on landform, foodwebs and carbon cycling is rare. Historical accounts of enormous volumes of wood on rivers in the temperate zone describe a scenario that has largely vanished and by consequence shorelines are severely wood-impoverished relative to their condition prior to intensive human settlement (Wohl, 2014). Thus, stable landforms that we see today along river corridors and lakes may reflect past processes when driftwood was more abundant. In the absence of modern wood, studying these processes, let alone connecting vestige landscapes to driftwood processes is difficult.

Study Area

A few large river catchments remain largely forested and unregulated, and the Mackenzie River of Canada is one that still exports large amounts of driftwood to the Arctic Ocean (Eggertsson, 1994). The Great Slave Lake is situated in the middle of the basin and its shorelines record a history of driftwood accretion throughout the Holocene. I use the shorelines of the Great Slave Lake to document processes of shoreline dynamics that influence rates of carbon sequestration, sediment storage and habitat formation. Findings in this study are good proxies for shoreline dynamics and landforms in marine and terrestrial water bodies before widespread historical deforestation and wood removal along major waterways.

Materials and Methods

We used a combination of field and remote sensing techniques to investigate driftwood processes. We flew ~800 kilometers of the lake shoreline in a two-seater husky aircraft, capturing oblique air photos to document the distribution of driftwood around the lake. We visited field sites on the ground to make observations about processes, survey topography, record measurements of wood, and core trees to establish rates of decay and land accretion related to drift piles. Knowledge of current onshore processes from field visits was combined with satellite imagery of shorelines in Google Earth and results from scientific literature to infer impacts of high wood loads on shorelines on large spatial and long temporal scales.

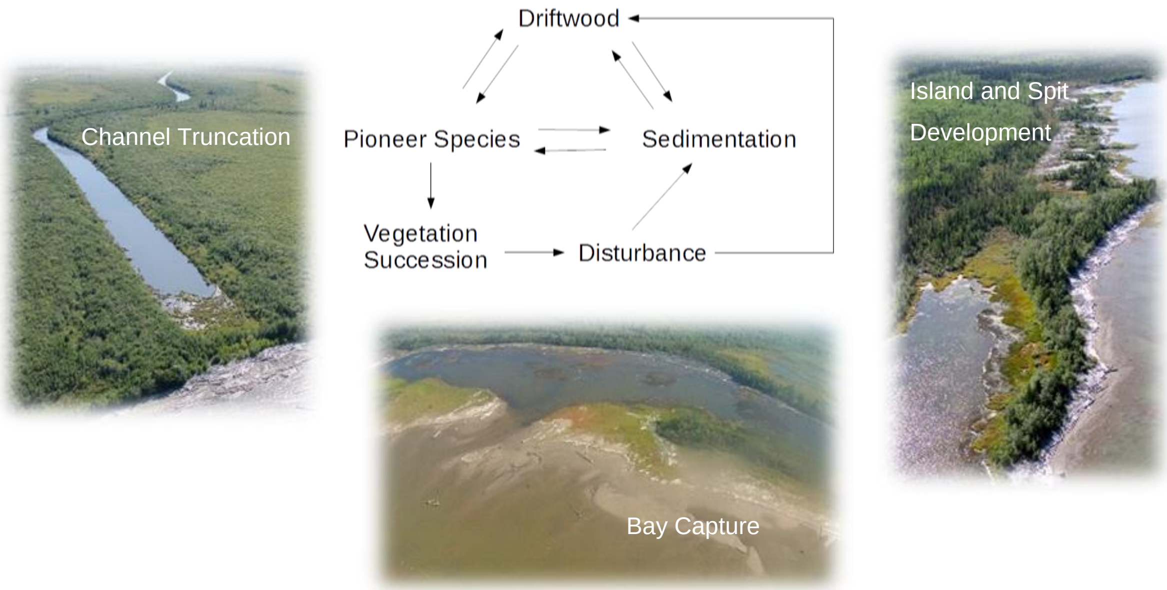

Figure 1: Conceptualization of feedbacks between driftwood, sedimentation and plant succession. Photographs illustrate several landforms resulting from driftcretions. Photos were taken on the shores of the Great Slave Lake, Northwest Territories, Canada (62.5N, 114W, WGS 84) on August 29, 2014 from a low flying aircraft.

Results

A driftcretion is a large concentration of driftwood that promotes sedimentation and interacts with vegetation to influence shoreline morphology. Driftcretions are expressed three main ways: as berms, as mats and as a piece-wise matrix. A piece-wise matrix is formed when driftwood is interspersed or layered in sediment, providing structural support to an otherwise unstructured medium. Mats are large, relatively flat accumulations of driftwood composed of a mix of large and small pieces, usually imbricated against each other parallel to the lake shore. Berms are raised ridges of driftwood that form parallel to the shoreline when seiches (lake tsunamis) or ice pushes rafted driftwood into linear piles. Driftcretions influence shoreline morphology on large spatial and long temporal scales by promoting island and spit development, facilitating bay capture, and abruptly truncating channels (Figure 1).

Driftcretions accumulate episodically, coinciding with years of high wood delivery from rivers. Based on tree core data, large accumulations occur every 20-50 years and 3-20 meters of land can be added to the shore by berms or mats in only one event. If a bay is captured or piece-wise matrices accumulate enough sediment, 10-50 meters of new dry land may be exposed and vegetated. Average rates of shoreline expansion associated with driftcretions are ~0.3m/y for berms or mats and ~1m/yr for piece-wise matrices. Large wood is abundant in Slave River deltaic sediments and have been dated back to ~8,000 BP (Vanderburgh and Smith, 1988). If a combined average rate of ~0.7m/yr is applied to this timescale, then driftcretions have impacted the morphology of the landscape up to ~6 km inland (ignoring lake level changes due to isotactic rebound and alterations in basin hydrology).

Discussions and Conclusions

Due to the length of time that loads of driftwood have been supplied to the Great Slave Lake, a complex mosaic of habitats and sinuous shorelines exist. Enclosed bays, land spurs and wind protected shores support large expanses of marsh that trap additional driftwood and sediment, and provide valuable habitat and refuge for fish, migratory birds and mammals. Off-shore standing water bodies resulting from bay capture and channel truncation are important sites of carbon capture. Recently deposited sediment (1975-2002 yr AD) in offshore lakes are made up of up 30-60% carbon (Mongeon, 2008). Driftcretions and their resulting landforms should be common on shorelines which receive a large wood supply and that have processes which store wood permanently.

Acknowledgments

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Contrasting patterns of wood storage in mountain watercourses narrower and wider than the height of riparian trees

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Abstract

Longitudinal wood distribution was compared for two watercourses in the Polish Carpathians: 2nd-4th-order Kamienica Stream, 14 m wide on average, and the 5th-order Czarny Dunajec River with mean width of 52 m. In the stream, both the number and the mean mass of wood deposits were unrelated to channel width, and this was reflected in a lack of the relationship between total wood storage (the amount of wood stored on unit channel length) and channel width. In turn, specific wood storage (the amount of wood stored on unit channel area) decreased non-linearly with increasing channel width. In the wide Czarny Dunajec, both the number and the mean mass of wood deposits increased as the river widened and this was reflected in a marked trend of increasing total wood storage with increasing river width. Here, the width-related variation in total wood storage was so high that it overcame the influence of increasing channel area on calculated values of specific wood storage, which also increased with increasing river width. This study shows that different mechanisms known to govern large wood retention in the channels narrower and wider than the height of trees growing on their banks are reflected in the contrasting patterns of wood storage observed in mountain watercourses of low to medium width and those of large width.

Keywords: *Large wood storage, Mountain watercourse,Channel width, Wood distribution*

Introduction

Many studies have indicated a tendency for the amount of large wood per unit channel area to decrease with the increasing width of a stream, attributing this pattern of wood storage within the river network to a range of factors such as an increasing mobility of wood as the ratio of piece length to channel width decreases or downstream decrease in the importance of channel storage in favour of floodplain storage (Gurnell et al., 2002). This study considers the patterns of wood storage in mountain watercourses narrower and wider than the height of riparian trees to demonstrate and explain how the patterns of total and specific wood storage change with changing channel width and how the two parameters are related in both types of watercourses.

Study Area

Two watercourses with marked variability of channel width were selected for the study. **(A)** 2nd-4th-order reaches of Kamienica Stream in the Gorce Mountains, with the average channel width of 14 m. In its 2nd-order section, with mean channel width far smaller than the height of riparian trees, Kamienica is a stream of small width. In the 3rd- and 4th-order sections, where mean channel width is smaller than the riparian tree height but larger than the average wood piece length (6.6 m), it is a stream of medium width.

Stream banks are almost fully forested, with the upper subalpine forest composed of spruce (*Picea abies*) and, downstream, the subalpine forest with spruce, beech (*Fagus sylvatica*) and fir (*Abies alba*). The height of mature trees in the riparian forest is similar along all the investigated sections of the stream (24 m on average). **(B)**17-km long reach of the 5th-order Czarny Dunajec in the foreland of the Tatra Mountains, with the average width of 52 m and morphology ranging from single-thread, bedrock and channelized river sections through bar-braided to island-braided and heavily island-braided ones. The river flows within a forested corridor composed of alder (*Alnus incana*) and willow species *(Salix eleagnos, S. purpurea, S. fragilis* and *S. alba*). With the channel width far greater than the height of trees growing on the banks (16 m on average), the Czarny Dunajec is a typical wide river.

Materials and methods

In Kamienica Stream, wood inventory was performed in the autumn 2012 in 70 channel segments of 100 m length. Wood deposits recorded here comprised logs and log jams. The volume of all logs was measured and to allow comparability of the results with the Czarny Dunajec River, it was converted to wood mass by multiplying by the wood mass estimate of 500 kg m^{-3}. In the Czarny Dunajec River, wood inventory was performed after the second of two floods in 2001, which recruited much large wood to the river and redistributed it along the channel. The inventory was taken in 89 river segments of about 100 m length. Each distinct wood deposit was classified as log, wood jam or shrub/whole tree. The volume of wood deposits was measured and their mass assessed by multiplying the wood/air volume of shrubs/trees and jams and the volume of logs by wood mass estimates of 50, 100 and 500 kg m^{-3}, respectively (Wyżga & Zawiejska, 2005).

In each watercourse, the mass estimates for individual wood deposits were integrated to obtain the values of total and specific wood storage (expressed as mass of wood per 100 m of channel length and per hectare of channel area, respectively). The number and the average mass of wood deposits were also determined for each channel segment. Potential relations between the number and average mass of wood deposits as well as the values of total and specific wood storage, and absolute and relative (i.e. scaled by the riparian tree height) channel/active zone width were explored through the estimation of linear regression models for each of the watercourses. Regression models were also estimated for each type of wood deposits distinguished in the studied watercourses. Finally, the results of the analyses for the watercourses narrower and wider than the height of riparian trees were integrated into a conceptual model describing how specific wood storage in mountain watercourses changes with the ratio of channel width to riparian tree height.

Results

Kamienica, the stream of small to medium width, was typified by a decrease in specific wood storage as the channel widened. The lack of a trend in the values of total wood storage reflected random distribution of the size (mass) and number of wood deposits. Such distribution can be attributed to similar lateral inputs of wood to channel segments of different width, coupled with either a general lack of transport of wood pieces (2nd-order reach with predominant perpendicular orientation of wood pieces) or their transport on short distances only (3rd-4th-order reach with predominant longitudinal and oblique orientation of wood pieces). The increasing number of log jams as the channel widened indicates a tendency of wood pieces to be increasingly aggregated with increasing size of the stream; however, the jams constituted a small proportion of the total number of wood deposits and the tendency could not change the general random distribution of wood deposits.

In the wide Czarny Dunajec, large wood was mainly recruited to the river in wide sections, whereas in narrow sections high strength of the banks and low channel sinuosity prevented bank retreat and the delivery of trees to the channel. All wood pieces were too short to span the channel even in the narrow river sections and the pattern of wood storage in the river generally mimicked the variation in river width. In the narrow sections, the lack of retention features prevented wood deposition, whereas high unit stream power and relatively high flow depth at flood conditions facilitated flushing out of wood to downstream, wider sections. In fact, a majority of the large wood deposited immediately downstream of a 7-km long, channelized river section was highly disintegrated and abraded, indicating long-distance transport, most likely throughout the narrow section. In the wide sections, the considerable length of eroded channel and island banks enabled intense delivery of trees from the local riparian forest, whereas the low unit stream power and the relatively low depth of flood flows facilitated deposition of transported wood. At the same time, the abundant occurrence of wood retention features in these sections enabled efficient structuring of a large proportion of wood pieces into jams.

Discussion and Conclusions

This study shows that different mechanisms known to govern large wood retention in the channels narrower and wider than the height of trees growing on their banks (Gurnell et al., 2002) are reflected in the contrasting patterns of wood storage observed in mountain watercourses of low to medium width and those of large width. In the streams narrower than the height of trees growing on their banks, equal inputs of wood to stream segments of different width and the lack of significant wood transport along the channels result in a non-linear, reciprocal relationship between the values of specific wood storage and channel width. As channel width becomes larger than riparian tree height, wood pieces tend to be preferentially stored in wider river segments. In the channels narrower than riparian tree height, their potential to retain wood largely reflects the ability of the longest wood pieces to dam the channels and trap smaller, more mobile pieces. The lowest values of specific wood storage typify watercourses with the channel width equal to or slightly greater than riparian tree height. Under such conditions, fallen trees already cannot span the channel and unit stream power of flood flows is greater than in wider channel sections, facilitating flushing out of wood to wider, downstream sections. In the channels wider than riparian tree height, the conditions preventing retention of large wood occur in gorge sections of unmanaged rivers and in narrow, channelized or incised river sections. In turn, wider river sections are typified by relatively low unit stream power, shallower water depth and the presence of major roughness elements such as bars or islands. All these factors promote deposition of floating wood which is thus preferentially deposited in wider river sections.

Relation between the specific and total wood storage differs between watercourses narrower and wider than riparian tree height. In the former, similar total amounts of large wood retained in successive stream segments are reflected in decreasing spatial density of wood as channel width increases. Watercourses wider than riparian tree height are typified by the increasing tendencies of total and specific wood storage as their channels widen. In the Czarny Dunajec, the tendencies reflected increased potential for the retention of all types of wood deposits rather than increased aggregation of wood pieces into jams in wider channel sections. In the watercourses wider than riparian tree height, both the spatial density and the total abundance of wood-related features will be thus greater in their wider sections. Different relations between the tendencies of total and specific wood storage in the two types of watercourses emphasize the need of reporting both the spatial density and the total amount of large wood.

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ECOSYSTEM TREND AND EVOLUTION IN FLUVIAL MORPHOLOGY: AN EXAMPLE IN CALABRIA

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Abstract

The basin management is steered towards a global approach where engineering and naturalistic techniques complement each other, supporting the natural trend of continental waterways until a stable equilibrium longtime. In this sense, the river, regarded as "hydro-system", extends from riverbed to bordering areas, known as peri-fluvial strips. This approach is particularly important in the morphological study of fluvial systems, located in anthropic areas. The fluvial morphology or, in other words, the whole of different shapes showed by rivers, develops on time under the action of different factors, human actions included, and it occurs as a "*continuum*" of structures without any boundaries between them. Mollard suggested in 1973 a morphological classification based on photo-interpretation that compares the linear forms with some factors as the solid transport at the bottom of rivers, the relationship between this kind of transport and the whole solid transport, the grain size and some physical/territorial factors, as the slope and the winding of riverbed. This study aims to analyze the evolutional trend of Crati river in a stretch of about 15 Km. between Luzzi and Bisignano towns through a comparative methodology that collates the fluvial morphology at different ages with a particular care to riverbed variations, owing to natural or anthropic events. Besides, together with the morphological analysis of riverbed, it has been applied in the catchment of Crati river an environmental and synthetic method, named Fluvial Functionality Index (IFF), to value the whole ecological status of the basin.

Keywords: *fluvial morphology, hydro-system, solid transport, river management.*

Study Area

The Crati river, rises at the slopes of Timpone Bruno mountain (1742 m a.s.l.) in the Sila Plateau, with the nickname of Craticello, and flows into the Gulf of Taranto between Mandria di Rizzo and Masseria La Foggia resorts. In the first stretch, it goes down from the supply area covering a slope of about 1500 m until Cosenza town (Caloiero et al.,1975). Afterwards, it goes on along the Crati Valley and after the dam of Tarsia, it outflows in Sibari plain until its outlet to the Ionian Sea. Crati is the longest river in Calabria with a length of about 91 Km and a catchment area of 2447.79 Km^2 (Fig. 1). In this area, it has been studied a stretch of about 15 Km. length between Luzzi and Bisignano towns in the basin valley of Crati river (Fig. 2).

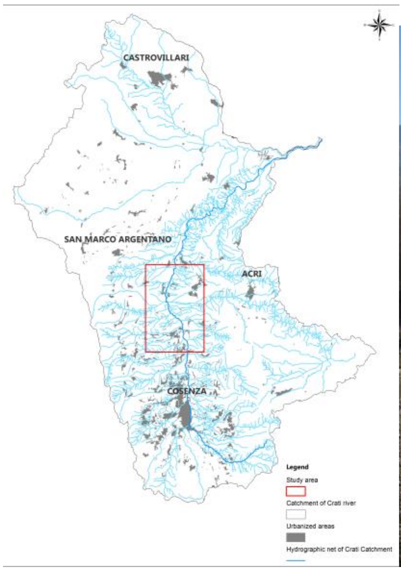

Figure 1: Catchment area of Crati river and location of studied area. **Figure 2**: Crati river in the studied area.

Crati valley is covered, for about 60% of its surface area by crops, a third of which are irrigated. The water supply, particularly in the summer months of July, August and September, is guaranteed by the river dam of Tarsia, in the southern region of Cosenza, with a capacity of 16 million m^3.

Materials and Methods

The research has regarded the collecting of bibliographic data, topographic maps and ortho-photos from the beginning of fifties until now to realize a digital mapping corresponding to the stretch of river analyzed. The cartographic basis are composed by maps IGM, in scale 1:25000, outcomes of mapping by photointerpretation performed in 1954 and 1995 and by aerial photography released from some flight plans realized in 1954, 1979, 2001, 2006, 2008, 2011 and 2012 years (Fig. 3).

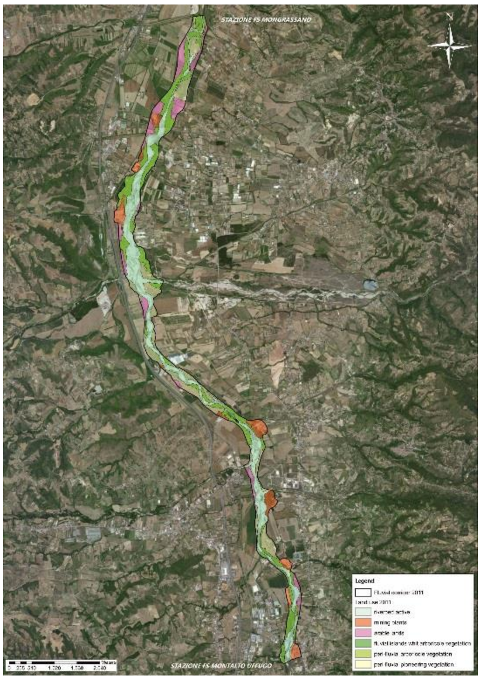

Figure 3: Land use map for the studied stretch realized in 2011 year.

The photographs, collected in this first step, have been scanned and geo-referenced through the support of a GIS software. So, through photointerpretation at video playing, it has been outlined, for each period, the fluvial fixture strip and, inside it, it has been characterized the main vegetation types, also those being in riverbed (Lenzi et al., 2000; Canal et al., 2007). Besides, it has been applied in the catchment of River Crati the Fluvial Functionality Index (IFF), particularly tested in the stretch analyzed. This synthetic and environmental method extends its range from the simple river channel to the whole fluvial ecosystem in an evolutional trend extended from microcosm to macrocosm (Callegari et al., 2009). Really, the knowledge of lotic environments needs, necessarily, an integration between different kinds of fluvial indicators. Finally, abiotic, biotic and environmental methods become a complement set to supply a whole and holistic vision of fluvial system (Callegari et al., 2010).

Results

The landscape of Crati river in the tested stretch shows, actually, many areas heavily exposed to human pressure that never have taken advantages from recovery actions on territory and/or on vegetation. Particularly, the drawing plants have upset some pieces of the riparian ecosystem leaving in some spots deep holes where groundwater table comes afloat. Really, the exploitation of water resources does not match with a steady monitoring and a correct fluvial management. The last flooding events occurred in 2008-2009-2010-2011 winter periods and in 2010-2011spring ones, confirm the heavy negligence in landscape management in spite of UE directives and planning instruments very detailed but never realized. The results, achieved until now, show strong riverine dynamics and a good resilience by the altered vegetal system along the fluvial corridor of Crati river.
Finally, the application of IFF method in the catchment of Crati river provides a mean value of 186 points corresponding to a good-mediocre functionality level of the fluvial system.

Discussions and Conclusions

The river management is a complex activity in which managers of water resources are frequently engaged to mediate between hydraulic safety and environmental needs. In this sense, some studies have shown that, for a right river management, it is necessary to regard the fluvial channel as an open system (Korpak, 2007). The development of fluvial landscape is, indeed, connected to the basin resilience against climatic changes and human drivers. So, a deep analysis at large scale and at long time could supply a reliable base for conservation and fluvial restoring policies (Molnar et al., 2002). Besides, from IFF application in the catchment of Crati river, it has been found a low level of biological functionality, particularly in the deposit and transport areas of the basin, where trophic nets are deeply upset and only some taxa of macro-invertebrates can survive, enduring conditions of high pollution, while the auto-depurative capacity of the fluvial system and its fluvial functionality are totally compromised. Therefore, the catchment of Crati river presents, altogether, a level of fluvial functionality good-mediocre in the 88% of its surface area, as highlighted by its map-making (Fig. 5).

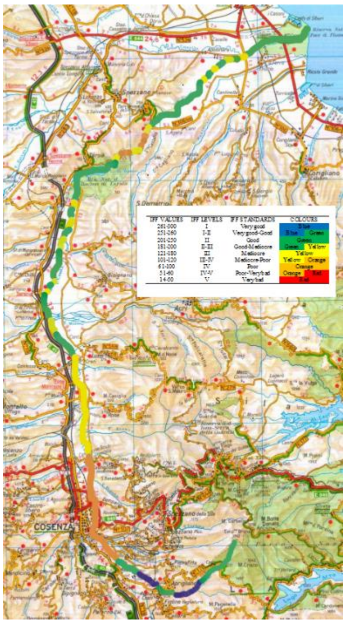

Figure 5: Map of fluvial functionality of Crati catchment.

Conditions of critical biological state are observable in the analyzed stretch, between the railway station of Mongrassano (Cs) and Montalto Uffugo (Cs), where are confirmed the bad biological conditions of Crati river and the poor morphological variety of its riverbed whose elements are confused along the waterway.

The results acquired by this study let to state that the landscape of Crati river, in the analyzed stretch, shows areas heavily affected by anthropic actions while other areas do not benefit of restoring actions on territory and on vegetation. The human pressure remains one of the main negative factors responsible of the temporal variation in fluvial morphology, also for the complete negligence and inefficiency of suitable authorities in territory management.

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Debris Dams on the Russian Far East Rivers

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Abstract

Debris dams on the rivers of the forest zone significantly affect river dynamics. They cause complicated channeling of the main stream, intensive riverbed transformations, local bank erosion and solid matter accumulations. Debris dams also cause problems for various engineering facilities like bridges, buildings and roads. In the taiga zone the number of dams and their structure depend on the river size, the specifics of riverbed and water regimes, the amount and composition of forests in the river floodplain. Debris dams are most common in mixed-forest regions of the Lower Amur. Much depends on the ratio between the size of trees and streams.The described specifics of debris dams were used as criteria for zoning the southern part of the Russian Far East. The description of debris dam formation specifics, dam frequency and average size was provided for each selected zone. Special attention was given to the areas, where these river processes are most active and aversively affect economic activities and the state of natural landscape in the mountain river valleys.

Keywords: *Debris dams, riverbed transformations, bank erosion, Russian Far East.*

Introduction

In recent decades negative impacts of hydrological phenomena have been increasing, causing significant damage to the natural environment and aggravating environmental problems in the region. Wood debris dams on the rivers is one of the dangerous phenomena, which negatively affects many aspects of economic activities on the Far East rivers.

Debris dams are usually formed in the forest zones of rivers, characterized with a well-marked flood regime. Their location on the river is determined by the river morphological specifics and therefore debris dams are usually formed at upstream parts of river islands, underwater accumulative formations, as well as river bends and places of river channeling. Debris dams also significantly affect the structure and dynamics of the riverbed and the alluvium composition in some parts of the river. These factors make studies of debris dams economically important.

Debris dams formed on the rivers of the forest zone, play a significant role in the dynamics of river channels (Chemekov, 1955; Polunin, 1983; Chalov, 2008; Chalov et al., 2010; Esin, Chalov, 2011; Zlotina, Berkowich, 2012 and others). Dams accelerate river-channeling, intensive riverbed deformations, local erosion of the river bottom and its banks or sediment accumulation in the channel. They often endanger various engineering structures, like bridges, buildings and roads. The number of debris dams on the taiga rivers mostly depends on the specifics of riverbed and water regimes, as well as amount of forests and their plant composition in the floodplains. Debris dams are found very often in mixed forests of Primorje, Sakhalin and Amur basin.

Materials and Methods

The study is based on data, obtained by the Institute of Water and Ecological Problems, Far Eastern Branch of the Russian Academy of Sciences in 2012 during expedition works in the valley of the Khor River middle reaches, one of the largest tributaries of the Ussuri River. Materials of the Hydrometeorological Service (Resources ..., 1972) and satellite images were also used. Debris dams are well seen in the satellite images owing to their light color.

The studied area is a passage of the Khor river between the Chui and Sukpai rivers (305 km - 269 km from the river mouth). It is nearly a straight river passage, oriented from north-east to south-west. In some parts the main channel is divided into several sub-channels. Usually, one major channel and 5-6 minor channels of different sizes are formed there. The river bottom and all accumulative forms of river reliefs are composed of boulder and pebble deposits.

Dozens of debris dams were studied in this Khor passage, both on the river main channel, and on its sub-channels and tributaries. Types of debris dams, their location on the river, the duration of existence, and the affects on the rivers were studied and described during the field works.

The Khor lower reaches are located within the ancient accumulative plain, which has a general inclination in the direction of the Ussuri River. According to its morphological characteristics the Khor riverbed is of a flood plain multichannel type. It is characterized with the furcation due to long-term directed accumulation in the valley of the Khor lower reaches in the second half of the Holocene (Makhinov, 2006).

Results

There are very few papers on wood debris dams on the rivers of the Far East in the scientific literature published in Russia in the last 50 years. They only describe these natural formations on different rivers of the region.

The occurrence of debris dams in the south of the Far East depends on a number of natural features of the region (Makhinov, 1999; Makhinov and Zolotukhin, 2012). Debris dams are rare in the narrow valleys of the rivers cutting the relief, and on the contrary, are very common in the wide floodplain valleys characterized with the intensive lateral erosion of the rivers. In mountainous areas, they are most frequent in inter-mountain basins and intra-mountain depressions or local extensions of river valleys.

There is a clear correlation between the dam frequency and the amount of forests and their species composition. Debris dams are rare in the northern part of the region in the light-coniferous taiga subzone. In the sub-zones of dark coniferous and coniferous-deciduous taiga they occur more often. Moreover, the frequency of debris dam noticeably increases from continental to coastal areas of the region. This phenomenon is determined with river water regime specifics under the growing influence of monsoons closer to the sea coast. The map of the distribution of wood debris dams in the Russian Far East south was compiled based on the analysis of available data and the authors' observations.

Timber harvesting and fires affect the river hydrological regime and make river runoff even more irregular. This leads to the activation of channel deformation, banks erosion, and consequently, to the increase of trees floating in the river and causing more frequent formation of debris dams. The final step of this process is the formation of a large number of small-size sub-channels, where the erosion is significantly weakened. As a result, fewer trees drop into water and the role of debris dams in the river channel formation decreases. Because of the irregular sediment flux in the sub-channels, in the areas of intense channeling the water flow gradually redistributes between the sub-channels, and one of them becomes a new mainstream. Again, the influence of debris dams on the river runoff becomes significant.

Large debris dams of several hundreds of trees at the mouths of rivers make a serious obstacle for salmon coming for spawning. Debris dams on mountain taiga rivers cause channel shallowing, clogging with muddy sediments, significant deterioration of spawning grounds, and even their rapid decay. It takes a long time for spawning grounds to form in new channels. It happens because the accumulation forms, suitable for fish spawning, develop in mature channels, formed a long time ago.

The analysis of debris dam location showed that they are usually formed at the beginning of secondary channels of the Khor and significantly affect the channel dynamics (Fig. 4). Debris dams let the water through, but block large-size alluvial material. As a result, such river passages at first turn into weakly running streams then are gradually filled with fine sediments and finally stop functioning.

Debris dams on the Khor main channel are often formed at upstream parts of large accumulative landforms such as young islands, middle-stream sand bars, large spits and underwater shoals. Here they reach considerable sizes up to 5 meters in height and dozens of meters in width. As a rule, debris dams block the smallest channel from bank to bank, thus accelerating intensive furcations of the river in this passage. As a result, despite the mountainous nature of the flow and coarse composition of alluvial material in the channel, river multi-channeling is highly developed there.

Large debris dams occur on the rivers, which size (especially their width) is comparable to the size of tree trunks (from 20 to 50 m). Many Khor tributaries (the Kabuli, Chui, and others) are like that. Here debris dams are very frequent and are small in size, as trees, fallen into the river, are not carried far because the river is rather narrow.

Rivers Khor, Gur, Anyui and some others have not yet been very seriously affected by anthropogenic activities. However, further intensive timber cuttings or frequent widespread fires in the river basin can accelerate river channel processes and the formation of new sub-channels. It is well-known that, when timber harvesting is carried out in the river basin, the number of wood debris dams there significantly increase compared to rivers, which basins suffer no tree cuttings.

Discussions and Conclusions

Forest vegetation has a significant impact on the nature and intensity of riverbed processes and the formation of riverbed reliefs in the Far East of Russia. The ratio between the size of trees and rivers is an important factor of such impact. The types of this ratio are described.

Debris dams are also frequent on larger rivers up to 150 meters wide, which flow through the forested lands. They play an essential role in the riverbed dynamics affecting river channeling, intensive riverbed deformation, local river bank and bottom erosion and a significant accumulation of alluvial deposits in the channel. On large rivers (Khor, Anyui, Gur in its middle reaches, Ussuri, Amgun and others) debris dams are formed in the secondary channels, and trees in a large number accumulate at the river banks.

Acknowledgments

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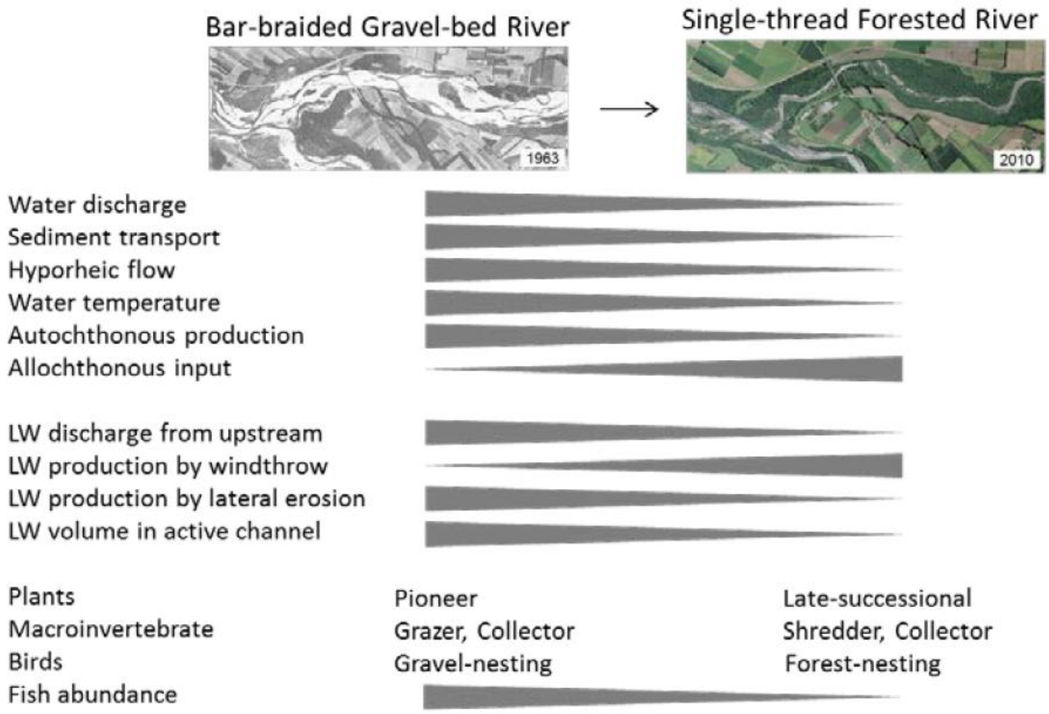
TOPIC 2 – Wood dynamics in rivers

Keynote speaker: **Angela Gurnell**

Presentation title: Wood, trees and changing river landscapes



Forest expansion on gravel-bars and floodplains, and expected changes in river and riparian ecosystem

(In: *Export of large wood and sediment at watershed scale, and predicted future changes of river and riparian ecosystems in Japan. F. Nakamura, J. Il Seo, T. Akasaka, Y. Yabuhara*)

Export of large wood and sediment at watershed scale, and predicted future changes of river and riparian ecosystems in Japan

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Abstract

The fluvial export of large wood (LW) was monitored in more than 100 reservoirs throughout Japan. Of all variables tested, watershed area was most important in explaining LW export, followed by annual precipitation. In southern and central Japan, intense rainfalls accompanied by typhoons or localized torrential downpours lead to geomorphic disturbances, which produce massive amounts of LW pieces into channels. However, these pieces are constantly removed by repeated rainfall events, and thereby LW export is supply-limited potentially making less LW accumulation than in northern Japan. Conversely, in northern Japan, where typhoons and torrential downpours are rare, LW pieces recruited by bank erosion, tree mortality and windthrow accumulate and persist on valley floors, and LW export is transport-limited. The sediment discharge along the latitudinal gradient also follows the above discharge pattern of LW, although watershed size effect differs between them. River incision and forest expansion on bars and floodplains in Japanese rivers becomes prominent, probably due to sediment mining in 1950s and '60s, dam regulation, sediment control by check dams and an increase in forest cover in headwater basins. These changes have already altered bird communities in riparian zone which are dependent on gravel-bed. The channel incision and forest expansion together with climate change should alter abundance of instream LW, habitat heterogeneity and food-web structure, and thereby biodiversity and ecosystem functions in rivers and floodplains.

Keywords: *Watershed size; Precipitation; biodiversity; Ecosystem function.*

Introduction

Precipitation patterns in the Japanese archipelago vary along a latitudinal gradient, and thus flood frequency and magnitude differ between southern and northern Japan. The most influential events are typhoons and seasonal rain fronts, which produce heavy rainfall. These events frequently hit southern and central Japan, whereas in northern Japan, a considerable proportion of precipitation occurs as snowfall and typhoon-related heavy rainfalls rarely occur. These differences in precipitation patterns in the Japanese archipelago might lead to differences in the magnitude and frequency of hydrogeomorphic disturbances, thereby regulating the dynamics of in-stream LW and sediment.

Sediment control of dams and gravel mining in rivers and floodplains cause sediment starvation, resulting in the rapid degradation of riverbeds. Consequently, rivers and floodplains become independent ecosystems, which has resulted in the further expansion of forests on bars and floodplains in Japan. The channel incision and following forest expansion in riparian zone should alter abundance of instream LW, plant and animal species that are dependent on gravel bars, and mutual trophic interaction between rivers and riparian ecosystems.

The objectives of this paper are to (i) investigate the differences in LW distribution and relevant export as a function of precipitation pattern and channel characteristics, (ii) examine relationship between LW export and sediment discharge, and (iii) predict future changes of river and riparian ecosystems in Japan.

Study Area

Local reservoir management offices in the Japanese archipelago remove LW pieces trapped by dam reservoirs, and many of them annually estimate the total volume (see Seo et al., 2012). Not only LW but also sediment discharge have been measured by most of the reservoir offices, and therefore we could examine the relationship between LW export and sediment discharge at yearly basis. We decided to examine the hypothesis presented by Seo et al. (2012) through field surveys. Our study was conducted in six watersheds with reservoirs where data on LW have been collected in Shikoku, southern Japan and in Hokkaido, northern Japan. The channel incision, forest expansion and bird species in riparian zone have been monitored in 109 Class-1 rivers by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in Japan. We would like to predict future changes of river and riparian ecosystems in Japan using these large databases for channel morphology, riparian vegetation and bird community provided by MLIT.

Materials and Methods

Fieldwork was undertaken during base flow conditions in autumn after the summer monsoon season in 2009. The dynamics of LW pieces can be affected by the channel geomorphology (e.g., width, gradient, surface form and obstruction). In each segment, we established 4-8 transect lines and measured the bankfull channel widths and the widths of the channel surface planforms. Then, we measured and estimated the total volume of LW accumulated within the bankfull channel widths in single-piece or log-jam form. We also used large databases for export of LW, sediment discharge and national census of river and riparian biota.

Results

The differences in precipitation pattern and resultant flood events between southern and northern Japan should influence LW export according to Seo et al. (2012). We examined the effect of precipitation intensity and water discharge on LW export per channel length (Figure 1). We employed cumulative daily precipitation greater than or equal to 60 mm (DPc⩾60) as the precipitation intensity (Figure 1a) and cumulative water discharge caused by DPc⩾60 as the runoff intensity (Figure 1b). Although LW export increased with both DPc⩾60 and the relevant water discharge, the corresponding slopes of the regression models differed between southern and northern Japan. In addition, in the range of comparable precipitation and runoff intensities shaded in Figure 1a and 1b, LW export was greater in northern Japan than in southern Japan, meaning more LW pieces can be transported by the similar level of precipitation and flood events.

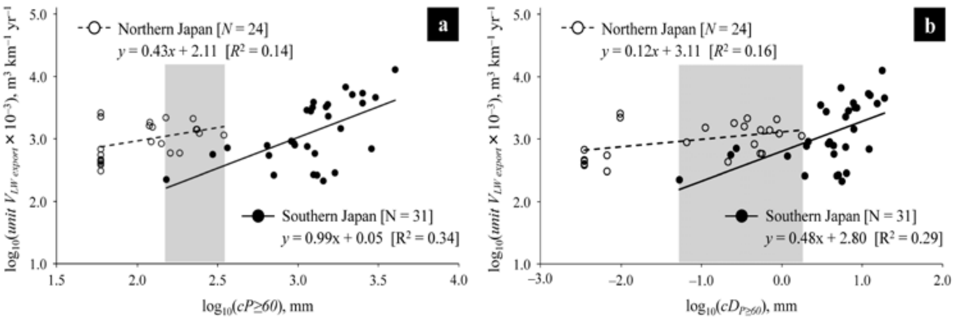

Figure 1 Relationship between unit VLW export and precipitation or runoff parameters in the six study watersheds located in southern and northern Japan, modified from the result of Seo et al. (2012); (a) unit VLW export－cP⩾60 relationship, (b) unit VLW export－cDP⩾60 relationship. The range of comparable precipitation intensity is shaded.

We found correlation between LW export and sediment discharge monitored at yearly basis, and sediment discharge along the latitudinal gradient follows the trends of LW export. The channel incision and forest expansion are prominent in many of Japanese large rivers (Figure 2), which alters material flows and biodiversity in rivers and riparian ecosystem.

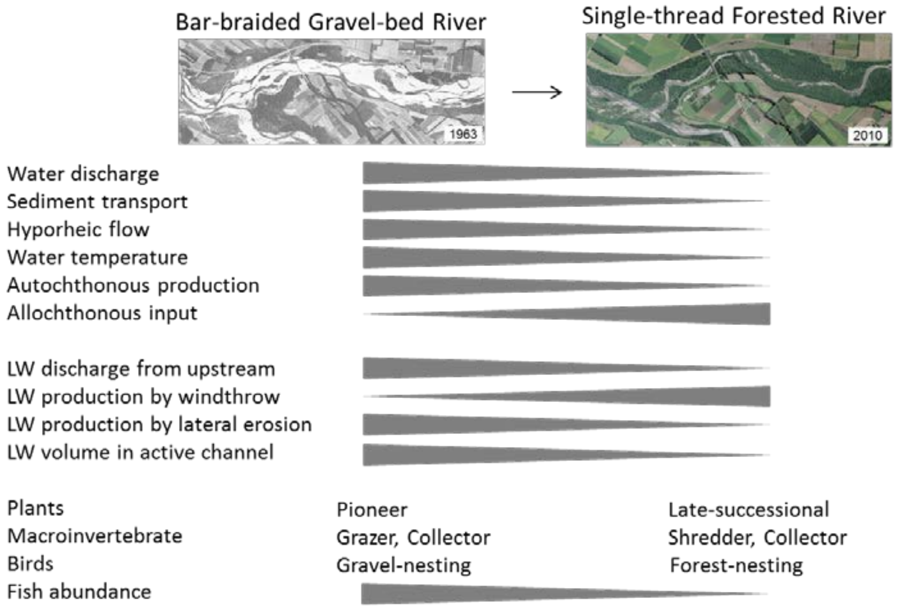

Figure 2 Forest expansion on gravel-bars and floodplains, and expected changes in river and riparian ecosystem

Discussions and Conclusions

We examined differences in LW distribution in six watersheds located in southern and northern Japan and validated the impacts of different precipitation patterns on the fluvial export of LW from river catchments. In southern Japan, intense rainfalls that are caused by typhoons or localized torrential downpours initiate landslides and debris flows, which introduce massive amounts of LW into channels. Gravel bars are widely developed by frequent flood events, and the LW temporarily stored on these bars is frequently moved and/or fragmented into smaller particles by the flood events. Therefore, the fluvial export of LW is supply-limited, with potentially less accumulation and a shorter residence time than in northern Japan. Conversely, in northern Japan, LW is mostly recruited by bank erosion, tree mortality and windthrow into channels rather than by landslides and debris flows. These pieces are accumulated in log-jams on the valley floors, particularly on the mature-forested floodplains, resulting in greater accumulation and longer residence times. Thus, the fluvial export of LW is transport-limited, and the pieces gradually decompose during long-term storage as log-jams.

Current river and floodplain changes accompanied by channel incision and forest expansion, together with an increase of high-magnitude flood events associated with climate change should alter future LW regime at watershed scale. We predict that export and in-stream LW may increase, insects and bird species dependent on gravel-bed decrease (Yabuhara et al. 2015), and energy flow may change from autochthonous production to allochthonous input that results in changes of macro-invertebrate and fish communities through food-web.

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Hydrologic regime controls pattern and architecture of woody debris in mountain streams

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Abstract

We examine the relationship between flow regimes and patterns of woody debris accumulations in spring-fed and runoff-dominated channels in otherwise similar bioclimatic settings in western Oregon, USA. Wood patterns in spring-fed channels reflect the nearly constant discharge regimes and overall channel stability: wood accumulates as individual, channel-spanning pieces and loosely packed debris jams, with little evidence of fluvial transport or reorganization. In contrast in runoff-dominated streams, wood occurs along channel margins or in densely packed debris jams, reflecting relatively frequent fluvial transport. These findings have implications for interpreting the long-term channel morphology, history, and evolution and directly affect the quality and quantity of habitat for organisms as well as the potential for wood-augmented disasters during floods.

Keywords: *woody debris, hydrologic regime, channel morphology, wood transport*

Introduction

Four decades of global research into the pattern, role, morphodynamics, and ecological consequences of wood in rivers has resulted in a voluminous literature, with few topics left unconsidered (Gurnell, 2015). Yet one question that has received little attention has been the degree to which the pattern and architecture of woody debris accumulations along rivers reflects the hydrologic regime of those rivers. Several observations motivate this question. First, it is well known that wood mobility, hence potential for transport and reorganization, increases downstream in response to both increasing channel depth and width as well as stream power (Braudrick & Grant, 2000; Comiti et. al., 2006; Mazzorana et. al., 2011; Ruiz-Villanueva et al., 2014). Flow regime is implicitly reflected in both changing channel geometry and stream power, but there has been little explicit attention to the coupling between flow regimes and wood mobility. Second, preliminary observations of woody debris accumulations in spring-fed streams with near-constant discharges are markedly different from those in runoff-dominated streams with highly variable hydrographs (Manga & Kirchner, 2000). A key aspect of spring-dominated streams is that flows rarely exceed bankfull, and transport of woody debris is rare, hence wood tends to accumulate with long residence times in places where it has entered by non-fluvial mechanisms, including blowdown and bank erosion. In contrast, in runoff-dominated streams of sufficient size for wood to be mobile, wood can be pivoted, floated, and entrained by the flow, leading to woody debris accumulations that distinctively reflect their fluvial transport history.

In this study we focus on how patterns of woody debris in mountain streams reflect the underlying flow regime of streams by comparing patterns of wood loading, piece orientation, location, and jam architecture and packing in spring- and runoff dominated streams in similar bioclimatic settings in the Cascade Range of the US Pacific Northwest. Differences are so great that we conclude that patterns of woody debris can actually be used as a useful field indicator of overall channel flow regime. These findings have broader implications for understanding shear stress partitioning, sediment transport, channel geomorphology, habitat availability, and potential for wood instability and associated natural hazards in mountain rivers.

Study Area

This study was carried out in four streams representing both stable (spring-fed) and variable (runoff dominated) flow regimes draining both east and west sides of the crest of the central Cascade Mountains in western Oregon, USA. The Cascades are a young volcanic arc broadly comprised in this area of both older (Oligocene to Miocene) and younger (Pliocene to Holocene) north-south trending zones (Sherrod and Smith, 2000). Differences in age, and corresponding differences in degree of dissection, weathering, and topography lead to radically different flow regimes in sometimes contiguous basins despite similarities in climate (moist Mediterranean), precipitation (fall through spring rain and snow) and vegetation (predominantly coniferous forests) (Ingebritsen et. al., 1992; Grant, 1997; Tague & Grant, 2004; Jefferson et al, 2010). Precipitation on the west side of the crest is markedly higher (averaging 2000-2500 mm/yr) compared to the east side (averaging 200-300 mm/yr). Although both sides of the crest are coniferous, the sharp climate gradient results in primarily *Tsuga* forests west of the crest and *Pinus* forests east of the crest; trees in both types of forests can be several centuries old and attain heights of 50 m or more.

Hydrologic regimes in spring-fed streams are characterized by flows that vary less than a factor of 2-3 over the course of the year, while runoff-dominated streams may vary by as much as two orders of magnitude (Hempel et. al., 2014). Channel gradients range from 0.01 to 0.06 and streams have gravel to boulder beds. Mature and old-growth forests along floodplains, terraces, and adjacent hillslopes are the primary sources of large wood within the channel boundaries in all streams.

Methods

In each of the four streams representing different hydrologic regimes we measured wood accumulations along 200-300 m reaches during summer low flows. In each reach we measured all wood larger than 2 m in length and 0.25 m in diameter. For each piece, we measured size (length, diameter), condition (fresh to decomposed), location and orientation with respect to channel margins, presence/absence of rootwads, evidence of transport in terms of sheared bark, branches, or other marks, and if part of a debris jam, total jam volume and architecture (closed or open framework). We sampled reaches during the summer low

Results

Preliminary results reveal stark contrasts in the way in which wood accumulates in streams with either stable (spring-fed) or variable (runoff-dominated) flow regimes. Wood in stable, spring-fed streams occurs primarily as channel spanning pieces or loosely packed debris jams with open frameworks (Fig. 1A). Pieces show little evidence of flotation or fluvial transport and are typically covered with dense, thick moss carpets. Some pieces and debris dams have living trees growing out of them that may be 10-20 years old or older. In some cases it is possible to identify root pits where the downed trees were originally rooted. In many cases logs have been incorporated into stream banks or anchor small vegetated islands. Few logs are present along channel margins except where the trees have fallen sub-parallel to the stream. Wood represents the dominant structural feature in these channels and accounts for a large fraction of total flow resistance and form drag (Manga & Kirchner, 2000).

In contrast, in variable, runoff-dominated streams, individual trees spanning the channel are rare; most wood occurs as marginal pieces or densely-packed debris jams with multiple size classes of wood showing evidence of transport (Fig. 1B). Marginal pieces are typically aligned parallel to sub-parallel to flow and often have been stripped of their bark and branches by the flow. Most pieces are fresh and moss accumulations and nurse logs are rare. Depending on the presence of boulders or other large roughness elements, wood may or may not be the dominant source of form drag in the channel.

Figure 1: Wood accumulations in (A) a spring-fed creek with spanning, cross-stream orientation, extensive moss blankets, and development of small vegetated islands, all indicating piece stability. *image: J. Hammond* and (B) a runoff dominated creek with marginal pieces oriented sub-parallel to channel, densely packed debris jams, absence of moss cover, and presence of scars and stripped bark indicative of fluvial transport and abrasion. *Image L.Hempel*

Discussions and Conclusions:

Differences in patterns and architecture in woody debris accumulations between streams having similar bioclimatic settings but geologically-mediated differences in flow regimes underscore the importance of flow regime as a dominant control on woody debris in mountain streams. Because flows range over 1-2 orders of magnitude in runoff-dominated channels, channel width, depth, and velocities all increase as power functions of discharge (Leopold & Maddock, 1953). This expansion of the channel during high flows allows woody debris to pivot, move, float and become entrained by the current. Redistribution of woody debris is therefore relatively common, probably requiring flow return periods on order of 2-5 years (Nakamura & Swanson, 1994; 1993), although large-scale mobilization and reorganization of wood may require events of 25-year return periods or greater (Johnson et. al., 2000; Nakamura & Swanson, 2000).

Large wood rarely moves in streams with stable flow regimes because channels have adjusted such that flows are nearly at bankfull most of the time. At these flows, the typically rectangular cross-sections are too shallow for wood to float, meaning that most pieces stay in place for long periods of time (multi-decades or longer), accumulating moss covers, decomposing in place, and often being incorporated into the banks or vegetated islands. In a real sense wood in these relatively small headwater channels literally becomes part of the channel, whereas in runoff-dominated streams, wood moves through the channel.

These findings have important implications for channel morphology and aquatic habitat. Essentially, stable wood anchors stable channel features (sediment patches, vegetated islands and bars) which, in turn, imparts additional stability to the channel. Reorganization of channel morphology and habitat is accordingly rare to non-existent in these streams, and we would expect that the ecology would be similarly biased towards species requiring stable substrates, an expectation that is supported by recent studies (Yamamuro, 2010). Relatively frequent wood transport in runoff-dominated streams contributes to frequent reorganization of the channel structure and corresponding habitat and contributes to the potential for propagating disturbances downstream (Nakamura & Swanson, 2000; Johnson et. al., 2000). Understanding how flow regimes control wood accumulations and patterns is therefore fundamental to properly interpreting the geomorphic ecologic role of wood in streams, and predicting its hazards potential and risks.

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Large Wood Dynamics in a Headwater Stream: Effects of Geomorphology on Transport

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Abstract

Understanding how and why Large Wood moves is critical to successfully harnessing the benefits of in-stream wood for river management. Wood has been shown to enhance geomorphological and ecological diversity through formation of logjams; however, many of the benefits provided are predicated on in-stream wood remaining in the same place over time. Despite the importance of wood in rivers, our understanding of the mobility of large wood remains limited. In this study individual pieces of large wood were tagged and surveyed over a 32 month period within a lowland forest river. Individual pieces of wood were found to be highly mobile, with 75% of pieces moving during the survey period, with a maximum transport distance of 5.6km. Multivariate analyses of data from this study and two other published studies identified dimensionless wood length as the important factor in explaining likelihood of movement.

A length threshold of 2.5 channel widths is identified for near functional immobility, with few pieces above this size moving. Where logjams persist over multiple years they were shown to be reworked, with component pieces being transported away and replaced by newly trapped pieces. The findings of this study have implications for river management and restoration. The high mobility observed in this study demonstrates that only very large pieces of wood of length greater than 2.5 channel widths should be considered functionally immobile. For pieces of wood of length less than the channel width the possibility of high rates of mobility and long transport distances should be anticipated.

Keywords: *Mobility, Logjams, Large Wood, Geomorphology*

Introduction

Although the geomorphological and ecological effects of Large Wood in rivers has been widely covered in the literature, the mobility of wood in natural streams has received less attention (Wohl et al., 2010). Many of the effects of large wood in rivers are dependent on the wood structure mediating changes to the local hydraulics and thus altering patterns of sediment erosion and deposition. In order for these changes in sedimentary processes to have an appreciable effect the wood needs to remain in the same place for a period of time, or a structure needs to be able to self-reinforce by trapping mobile wood in the channel. In this way the stability of wood in a system can be seen as a prerequisite for many of the ecological and morphological benefits associated with in-stream wood.

Understanding how and why in-stream wood moves is a particularly timely issue as river managers are increasing using engineered logjams (ELJs) as part of stream restoration and rehabilitation schemes. In order for these schemes to be widely successful it is vital to be able to predict how the wood may move over time, and also be able to design ELJ structures with a higher probability of stability. Despite the importance of understanding wood transport field studies, particularly those over multiple years, such studies remain rare

(Bertoldi et al., 2013; Schenk et al., 2014). This study aims to address this gap by measuring the transport of wood in a small headwater stream over multiple years by tagging and surveying wood pieces.

Study Area

The study was conducted on the Highland Water, a 3rd and 4th order tributary of the Lymington River, Hampshire, UK. The river is within the New Forest National Park, and is a mix of semi-natural, channelised and restored sections, making it an ideal location to study the effects of channel type on Large Wood mobility.

Materials and Methods

Five 150m long reaches were used as study sites; 2 channelised reaches, 2 naturally sinuous reaches and one restored reach. All pieces of Large Wood (>1m long & >0.1m diameter) within the channel and floodplain of each reach were tagged (n=162) and their position recorded with a total station in multiple surveys over 32 months. Characteristics for each piece of Large Wood were also recorded to allow statistical analysis of movement and Large Wood parameters to be conducted.

Results

Of the 162 pieces of large wood tagged, 39 were surveyed in the same location during the entire survey and 123 were found to have moved. Of the pieces moving 86 were surveyed in a new location giving a minimum transport distance. Overall mobility was higher in the seminatural and restored reaches (80%) than in the channelised reaches (67.2%, p=0.003).

The range of measured transport distance was 0.36 – 5600 m, with six pieces moving in excess of 500 m; mean transport length of recorded movement was 148 m (standard deviation 6653 m) with a median transport length of 5.3 m (sd 67.0 m).

Data were combined with this study and two others from the literature (Keim et al., 2000; Wohl and Goode, 2008), binary logistic regression on the aggregated data showed dimensionless length (L* - piece length/channel width) and dimensionless piece diameter (D* - diameter/bank height) to be the best predictors of movement (G=21.624, DF=2, p<0.000, n=434).

Discussions and Conclusions

The results of this study show wood can be highly mobile in forest rivers. Over 75% of pieces moved over the 32 month study with a maximum distance of 5.6km; substantially further than would be expected based on results from other studies.

Mobile pieces of wood were preferentially trapped by logjams, with 69.8% of mobile pieces resurveyed within logjams, compared to 13.9% in the channel margins and 16.3% on the floodplain. By tagging individual pieces of wood we were able to show that even logjams which persist in the same location are actually cycling individual pieces of wood through them and constantly being reworked during floods.

Multivariate analyses show dimensionless length to be an important factor explaining mobility and transport distance in all contexts with few pieces of dimensionless length over 2.5 moving. Multivariate analyses also show dimensionless diameter, branching complexity, wood type and location can all be important factors in explaining mobility and transport distance, but this depends on context. Based on our results we propose a conceptual model to explain the changes in relative importance of wood characteristics and mobility in different geomorphological and forest settings (Figure 1).

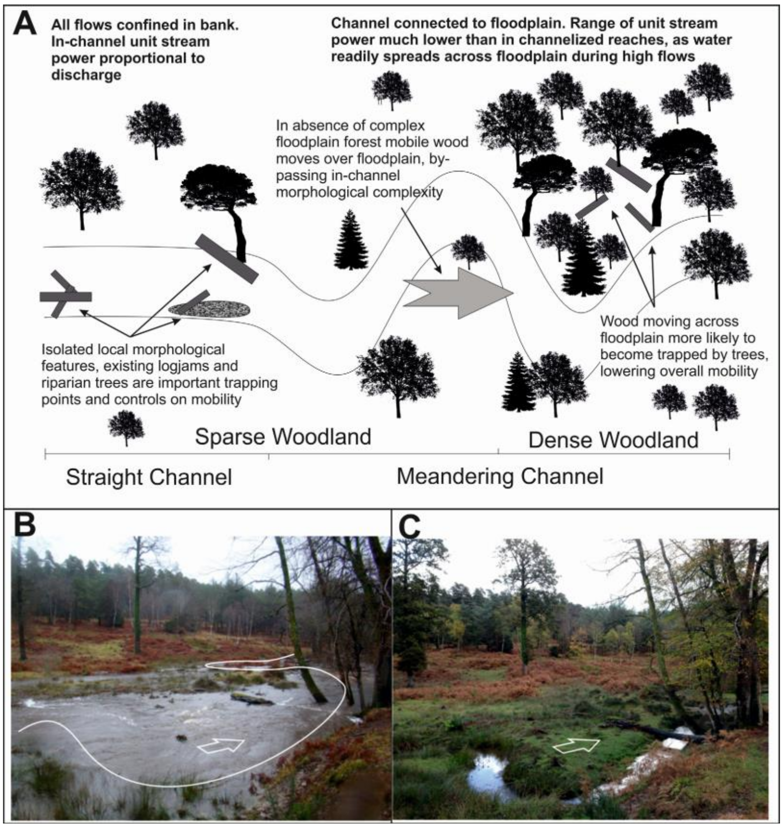

Figure 1 - Conceptual model of variations in wood transport controls between three river environments: channelized, meandering with sparse tree density and meandering with high tree density. (a) Conceptual model showing relative importance of different controls on wood mobility and transport. (b and c) field photos demonstrating change in flow-pathways during high discharge event (Figure 6b) compared to base flow (Figure 6c) in a reach connected to its floodplain. In a high-discharge event flow over the floodplain is deep and moving via alternative flow-pathways in a predominantly down-valley direction, channel planform is sketched onto image as white line. Reproduced from Dixon & Sear (2014)

Acknowledgments: This research was funded by the UK Environment Agency

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Large woody debris in an estuary: census data and transportation

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Abstract

No prior census data for an estuary is known to the authors despite their environmental and economic importance and the significant differences between a fluvial channel and an estuarine channel. This paper summarises 8 years of data collection and interpretation of Large Woody Debris (LWD) in the Snowy River estuary in south-eastern Australia, providing quantitative data on the amount, sources, transport and decay of LWD, and outlines procedures for estuarine LWD studies and data analyses.

Keywords: Large woody debris*; Estuary; Census; Classification, Transportation.*

Introduction

In rivers, large woody debris (LWD) has been shown to provide habitat for fish and crustaceans and to influence channel and bank sour and accretion. While numerous studies have looked at the roles of LWD in rivers, the sources of LWD and its transport in fluvial channels, there have been few studies of LWD in estuaries. Conditions in estuaries differ from rivers in several important ways:

- Tidal action leads to reversing flows and frequent cyclic changes in waterlevels that may transport or embed LWD even when river flows are low
- Tidal action facilitates trapping of LWD on intertidal bars and shoals
- Channels are wider and generally deeper, so log jams are less likely
- The wider channels mean that wind action is quite significant
- More intensive land use results in an increased supply of LWD from anthropogenic sources

In this paper we report on 8 years of data collection and interpretation of LWD in the Snowy River estuary in south-eastern Australia, providing quantitative data on the amount, sources, transport and decay. The paper outlines the simple and robust procedures for estuarine LWD studies and data analyses, based on our field experiences.

Site and methodology

The estuary studied was that of the Snowy River (figure 1), which is one of Australia's major streams, rising in the Great Dividing Range, flowing through rugged forested country and then a broad fluvial plain 12 km upstream of the town of Orbost. A few kilometers downstream of Orbost the river merges into a mature barrier estuary, where it is joined by the smaller Brodribb River, before discharging to the sea at the village of Marlo. South eastern Australian estuaries are characterised by microtidal tide ranges, wave-dominated inlet/entrance forms and a highly variable regime of catchment inflows.

To define the quantities of LWD and to gain a measure of the residence time and rate of replenishment, five comprehensive censuses of LWD throughout the estuary and two partial surveys were conducted over 8 years. On each census the following observations were made:

- Location GPS
- Photographic record
- Position and orientation relative to waterline
- Type (whole tree/trunk & root/trunk & branch/trunk/branch/root)
- Dimensions and size class
- Condition
- Scour/deposition depth and location

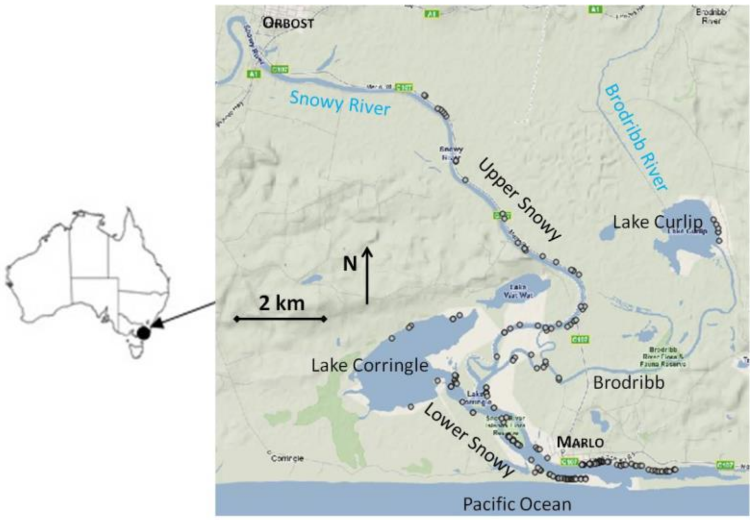


Figure 1: The Snowy River Estuary in south-eastern Australia and sites of LWD in 2004, note the concentration of LWD in the lower estuary near Marlo

Following each of the surveys, the quantities, condition, orientation and elevation of each size class were related to the location and, where possible, to physical variables of the estuary. Maintaining consistency of the classifications of size, condition, orientation and scour/deposition was a major concern as the project extended over 8 years with annual changes of field observers. Consistency from year to year and between teams in a year was based on continuity of supervision by both authors, use of photographs of all LWD, a training session, the use of objective measures wherever practicable, and by using standardised data recording sheets. Despite some changes resulting from experience gained, the data sets are essentially consistent from location to location and year to year.

Several additional projects were designed to address specific questions. These projects included:

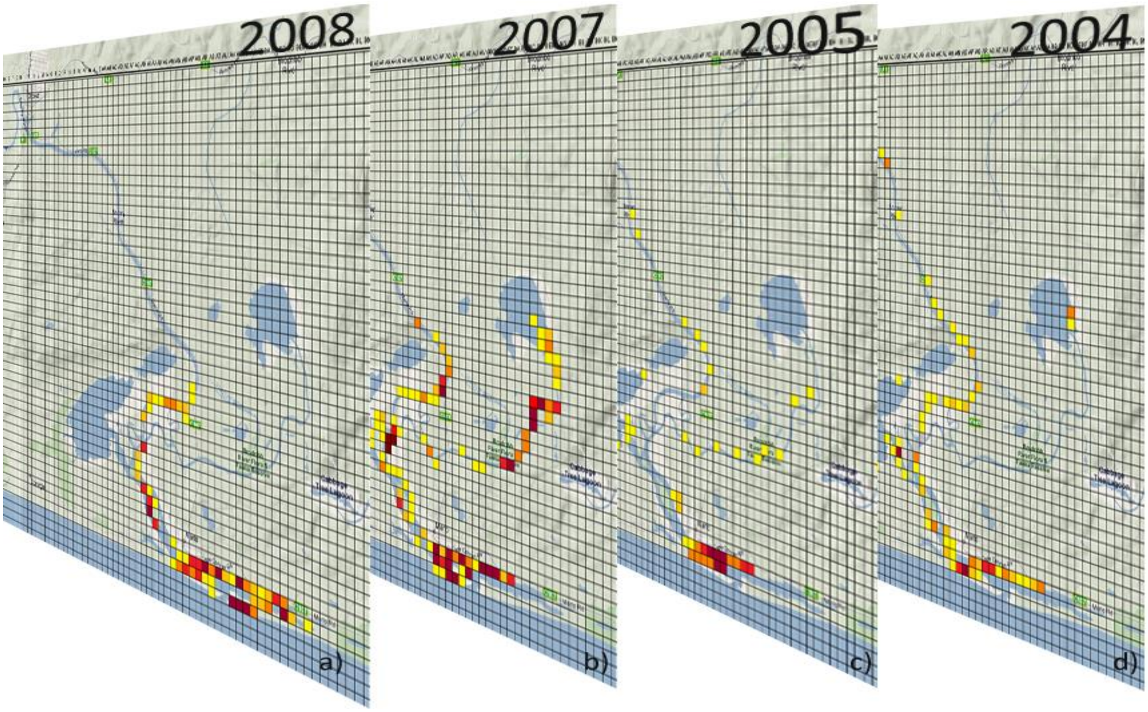
- assessing the lower fluvial reaches of the rivers as a possible source of LWD of specific tree species
- using local hydrodynamic observations to explain bank scour and accretion caused by LWD
- towing instrumented LWD to determine drag coefficients and the relative roles of wind and currents
- using GPS tracking to determine the factors causing local concentrations of LWD and speeds of travel.

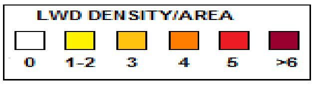
Results

The number of pieces of LWD found in 4 of the 5 censuses are shown in figure 2. There are very large differences in concentration from place to place and from year to year. Between 2004 and 2005, there was a general movement downstream but little new LWD introduced. Between 2005 and 2007 there was a major injection of LWD, mostly brought down the Snowy River by the floods in June and July 2007 together with a lot of smaller pieces from local bank erosion along the Brodribb in the floods. Between 2007 and 2008 this LWD appears to have moved downstream.

Regions of high concentration have been studied in more detail. Surveys have shown that the Islands and the beach opposite the estuary inlet are high intensity areas due to both wave and tidal action increasing stranding, and clearing to accommodate increased human activity has increased LWD near the mouth.

Space does not permit most of the measured parameters to be shown here, but figure 3 provides a sample of the distribution charts and the comparisons that may be made. In this example the condition of the LWD at two sites in the same year is used to show that the LWD degrades as it moves downstream from the Upper Snowy to the Lower Snowy, showing clearly that the dominant movement there is downstream. Movement into Lake Corringle, on the other hand, is predominantly upstream on a flood, then downstream over the subsequent years. The fact that the decay and weathering are quite advanced shows that the residence times in each major reach are long, as confirmed by repeat observations on many pieces of LWD.





Units are pieces of LWD per cell; cells are 200 x 200m

Figure 2: LWD distribution for four of the census years. The higher concentration in the lower estuary and the annual variability, particularly in the upper Snowy and Brodribb Rivers may be seen (The upper Snowy and Brodribb Rivers were not surveyed in 2008)

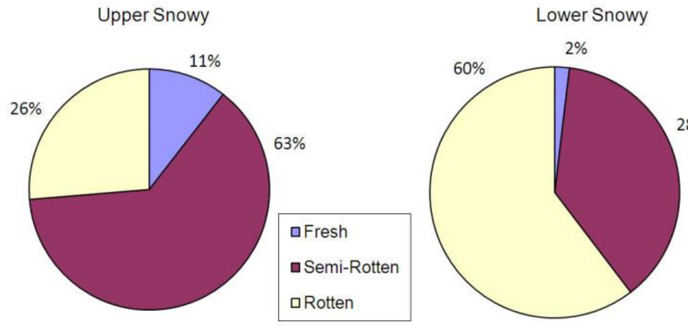


Figure 3: LWD condition in 2006 in two reaches, showing progressive decay and weathering downstream

Conclusions

There is a significant quantity of LWD in south-eastern Australian estuaries, derived from many sources including river flood flows, local bank erosion and anthropogenic sources. Wind and tide are as important as river flow in transporting and stranding LWD. Estuarine LWD contributes to localised scour and accretion and hence to the modification of estuarine habitat.

Biomechanical aspects of native European black poplar (*Populus nigra* L.) under hydrodynamic loading in Southern Italy

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Abstract

Cuttings of seed originated European black poplars growing in two riverine environments of Southern Italy, which are geographically close, but geomorphologically very different, have been planted in Short Rotation Forestry coppices and subjected to the same rotation length regime. The two different 3-year-old shoot poplar ensembles exhibit statistically similar morphological traits, but stems with different modules of elasticity. We verified that the differences in the observed elasticity are also relevant from a hydrodynamic perspective. The results suggest the possibility that poplars adapt their biomechanical properties to the dominant hydrodynamic forcing, as a result of their prolonged interaction with the local flood regime.

Keywords: *vegetation bending; wood elasticity;* Populus nigra

Introduction

Riparian plants interact with water and sediment flows and can influence river morphodynamics, for instance by colonizing inundated alluvial sediments and then trapping and stabilizing sediments to build pioneer landforms (Gurnell, 2014). Riparian woody plants exhibit several traits resulting from their adaption to the pressures of the river systems, such as hydrodynamics loading, shear stresses and sediment dynamics. A few studies have evidenced that the European black poplar (*Populus nigra* L.), a very common riparian woody plant in Europe, adapted its morphological traits to cope with the hydraulic force and the prolonged submersion periods, according to the dominant fluvial processes (Corenblit et al., 2014). In this study we compare the biomechanical traits of three-year-old shoots of European black poplar belonging to two ensembles of stools managed in a Short Rotation Forestry plantation, which induces physical disturbance regime comparable to the fluvial systems. The two ensembles of stools from cuttings of adult trees generated by seeds were collected in two different riverine sites of Southern Italy, just twenty kilometers apart.

Study Area

In 2007, cuttings of European black poplar were collected from adult tree (sex not determined) in natural stands along the Ripiti and Badolato streams, in Cilento (Campania Region, Southern Italy). The two sites are characterized by the same climatic and hydrological regimes, but have very different morphological features. The surveyed Ripiti reach subtends a catchment area of 100 km^2 and is characterized by a braided channel with longitudinal and transverse bars and eroding banks (Figure 1). The surveyed Badolato reach subtends a catchment area of 40 km^2 and is characterized by an entrenched meandering riffle/pool channel, with low gradients and high width/depth ratio (Figure 2).

The collected cuttings have been then planted in the “Azienda Sperimentale Regionale Improsta” (Eboli-Salerno, Campania region), within an experimental plantation managed according to a short rotation coppice with low external energy input. The cuttings grew as single-stems till the fifth year after plantation (2011) and were then coppiced. After coppicing, multiple shoots sprouted from the base of the stumpand the poplar plantations became multi-stemmed.

Figure 1: Plan and cross-sectional view of the surveyed reach of the Ripiti stream

Figure 2: Plan and cross-sectional view of the surveyed reach of the Badolato stream

Materials and Methods

During the third multi-stemmed growing season (2013), ten stools were selected in a systematic sampling from each of the two ensembles of Ripiti and Badolato poplars. Several morphological traits and physical properties were measured, such as number of shoots, mean height, basal area and dry biomass. Also one dominant or intermediate shoot from each of the ten stools were randomly selected for an indirect estimation of the Young Elasticity Module *E* in the proximal part of the stem (first 100 cm from the base), by means of an indirect acoustic method. This method entails the measurement of sound transit-time along a living wood stem to estimate the velocity of the wave sound propagation. Afterwards, the same shoot was harvested and a 10 cm long wood sample was collected in the median part of the first 100 cm of the sampled stem to estimate the fresh wood specific gravity. The module of elasticity *E* was then estimated as the product of the square velocity and the fresh wood specific gravity.

In order to assess the relevance of the differences observed in the estimated Young elasticity module *E* from a hydraulic perspective, we evaluated the bending of the individual stems under the hypothesis of complete submergence within a flow of different mean velocity, following the numerical model suggested by Chen (2010). This model predicts the bending of a woody vegetation beam allowing for large deflections, as it is the case of the riparian woody vegetation exposed to loads of a river flood.

Results

The morphological traits and the physical properties of the Ripiti and Badolato 3-year-old shoot ensembles did not exhibit statistically significant differences in mean and variance, except for the Young elasticity module (Figure 3). Ripiti poplars exhibit Young elasticity modules from 8082 to 13179 MPa (mean 10146.09 MPa and std ±1409.20 MPa), while Badolato poplars exhibit values from 5649 to 12537 MPa (mean 8438.58 and std ±1731.58 MPa).

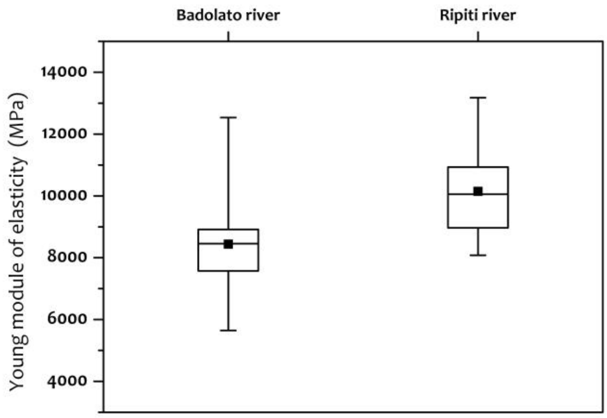

Figure 3: Young module of elasticity for each 3-year-old shoot provenances Ripiti and Badolato. The symbol ■ and − represent mean and median value respectively, the box represent the first and third quartile, and the whiskers maximum and minimum values. .

Figure 4 shows the bending behavior of two stems, with the same height and basal diameter, taken equal to the average values of the examined samples, while different Young modules, respectively equal to the average value of the Ripiti and Badolato shoot samples.

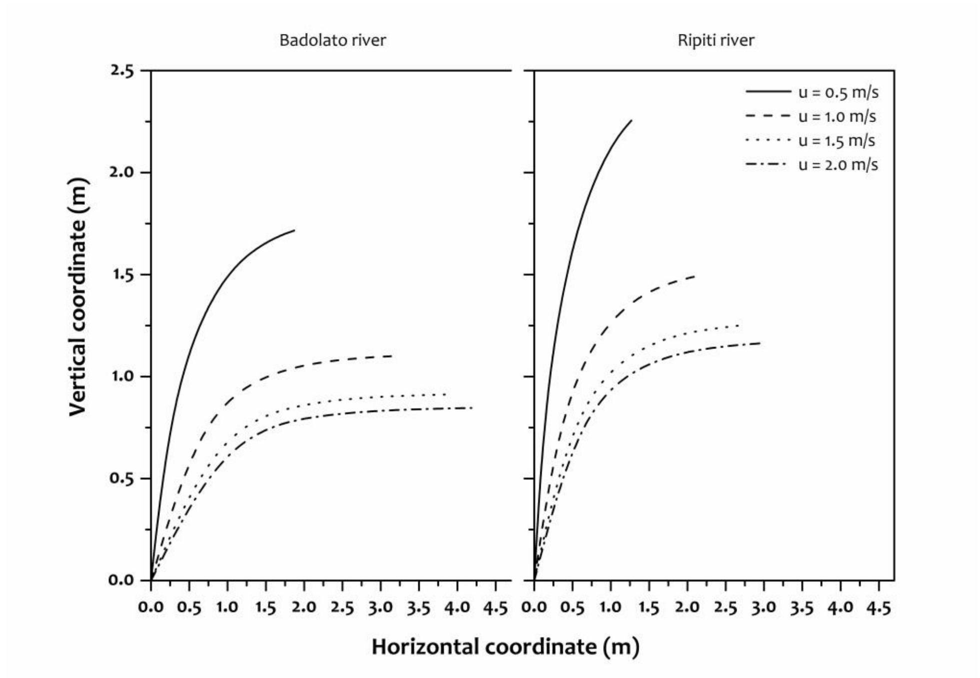

Figure 4: Nonlinear large deflections of Ripiti (left) and Badolato (right) shoot poplars under complete submergence for different flow velocities.

Discussions and Conclusions

The European black poplar (*P. nigra*) has evolved multiple adaptive traits to fluvial system disturbance factors. The results of this study suggest that it also adapts its biomechanical properties to the dominant hydro-morphological regime of its riverine environment. Plants with the same gene pool but coming from morphologically different riverine environments, may reflect different dominant biomechanical properties, which might be relevant for designing local sustainable management and restoration plans of rivers and riparian systems.

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Woodless rivers in the middle of forests

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Abstract

Logging in Oregon began in the 19th century and by the early 20th century many rivers in the region had been severely altered by log transport. Changes included removal of virtually all instream wood, removal of riparian vegetation, scouring of streambed substrates, and high width to depth ratios. Although rivers have not been used for log transport in more than 60 years, habitat conditions have not appreciably improved. We conducted extensive physical habitat surveys in two undammed watersheds on the east side of the Willamette Valley that were used for log transport. Both systems still exhibit impacts from log transport. The Calapooia River has 11.3% bedrock substrate, 0.6 pools per km with a residual pool depth >1 m, and 5.2/km of functioning pieces of wood. Mosby Creek has 60% bedrock substrate, 3.4 pools per km and 2.1 pieces/km of wood. Significant improvement is unlikely to occur until the abundance of large wood in these channels increases. The riparian trees established following the original logging have not yet achieved sufficient size to provide wood large enough to initiate recovery, and this material may not be produced for decades or centuries. Restoration of freshwater habitat conditions is considered a key element for the recovery of depressed fish populations in western Oregon. A combination of active restoration of desirable channel features and land management practices that restore processes that maintain habitat in the long term may offer the best opportunity to increase salmon and steelhead populations.

Keywords: *historic logging practices, wood loading, long-term outlook*

Introduction

The Pacific Northwest region of North America was settled by Europeans in the mid 19th century. These new residents immediately began to utilize two of the most prominent natural resources of the region: trees and salmon. The streams and rivers salmon depend on are heavily influenced by the forested landscape through which they flow. However, historical logging practices reduced the productive capacity of rivers. Many rivers were used for log transport during harvest of the primary forest, a process that entailed modification of the channel to enable logs to be floated to downstream mills and use of splash dams to provide sufficient flow (Maser and Sedell 1994). In-channel wood was removed to facilitate log movement and stream beds were heavily scoured by log drives. Logging of riparian trees that occurred during this period has retarded recovery of productive channel conditions because trees have not yet reached sufficient size to produce wood large enough to influence channel form and sediment, nutrient, and organic matter routing in larger channels. Degradation of stream habitat, coupled with impacts on estuarine systems and overfishing, caused a dramatic decline in anadromous fishes (Nehlsen et al. 1991). Since the advent of modern forest practices in the mid-1970s all fish bearing streams are buffered. Despite improved practices, many larger river reaches remain in poor condition. Here we document legacy impacts of historical logging practices on stream characteristics, including wood abundance, pool frequency and substrate condition, and describe the timeline and processes that led to woodless rivers. We also discuss the implications of this condition for fish and fish habitat and describe some of the restoration actions being implemented to accelerate large wood recruitment and habitat recovery.

Materials and Methods

We conducted detailed surveys of two undammed rivers that drain the eastern slope of the Cascade Mountains in western Oregon, the Calapooia River and Mosby Creek. The upper 24 km of the Calapooia River were surveyed in 2009. The survey counted and measured pieces of functioning wood (≥10 cm dia. and ≥2 m length within the bankfull channel). For each 100 m section, percent areal composition of substrate was estimated into four categories: % bedrock, material >128 mm, 4 to 128 mm, and <4 mm. A similar survey of Mosby Creek was conducted in 2008 by Oregon Department of Fish and Wildlife (Kavanagh 2008), and we report on a 29 km reach in the upper, forested watershed. We compared our results to a survey of 46 reference streams in the Oregon Coast Range (Thom et al. 2001) where the mean active width was slightly narrower than our case study streams. We tracked harvest history and natural disturbance over the past fifty years to understand current conditions and how past disturbance has influenced channel condition.

Results

Figure 1: Log drive (left) on the upper Calapooia River. Log drives occurred through the middle of last century In a current photo (right) note both lack of instream structure and the small size of trees along the channel.

The mainstem of the upper Calapooia River is representative of larger channels in western Oregon impacted by early logging and log transport. The channel lacks structural complexity and pool habitat. The 24-km surveyed reach had 11.3% bedrock substrate, 0.6 pools with residual pool depth >1 m per km, and 5.2 functioning pieces of large wood per km. Substrate was consistently coarse in the surveyed reach, with median clast dimension between 117 and 143 mm and frequent areas scoured to bedrock. in the upper 29 km of Mosby Creek the channel was approximately 60% bedrock substrate, 3.4 pool/km, and 2.1 wood pieces/km. Results from both surveys found <0.1 key pieces per km (10 m long and >60 cm dia.). Compared to streams in western Oregon not impacted by historical logging, these two rivers have an order of magnitude less wood (Table 1).

Table 1. Typical range off wood loading in western Oregon (n=46) [1]

Large Wood		Percentile	
	25%	Median	75%
Wood Pieces[2]	8	16	24
Key Wood Pieces[3]	0.3	1.4	2.5

1. Mean active channel width 10.6 m
2. LW > 3 m L and > 60 cm dia/100 m
3. LW > 10 m L and > 60 cm dia/100 m

Discussions and Conclusions

Habitat of larger streams and rivers in the western Oregon still exhibit influences from early logging practices. These channels have relatively little large wood, low frequency of large pools, and coarse substrates. Our results demonstrate that these poor habitat conditions persist in channels used for log transport a century ago. The simplified channels we observed in this study did not exhibit structural elements of habitat generally considered to be desirable. Percent pools and functional large wood are well below the criteria set by Oregon Department of Fisheries and Wildlife (medians – 1.5 deep pools and 160 pieces of large wood per km; Thom et al. 2001). Current habitat conditions limit biological productivity and may be inhibiting the recovery of salmon and steelhead populations in the region. Complex habitat has been associated with increased benthic production and physical habitat and water quality conditions favorable for salmonid fishes.

Despite improvements in forest management practices over the last several decades, conditions in many channels have not recovered. Given the pivotal role that wood plays in creating productive habitat, significant restoration of channel conditions cannot occur until wood inputs of sufficient size to affect channel form are available. In many cases, projections suggest that this wood will not be available for decades or centuries (Welty et al. 2002). We suggest two complimentary strategies to address this problem. First, establish measures to ensure that locations with high potential to deliver wood to channels will ultimately support trees of sufficient size. These delivery areas include not only riparian areas but certain upslope locations that have high potential to deliver wood to channels as a result of landslides and debris torrents (Reeves et al. 1995). Second, accelerate development of desirable channel features by restoration actions such as adding large wood and boulder structures. Enhancement of stream habitat has been implemented for decades with generally positive effects on habitat conditions and abundance of salmonid fishes. However, failures of some large wood projects, especially related to durability during high flows, have tempered expectations of the effectiveness of this approach. This perception has focused many restoration efforts away from the main channel and to channel margins and side channels (Roni et al. 2002). While these efforts can provide refuges and seasonal rearing habitats, they do not address the loss of main channel habitat complexity due to early logging. Enhancing the complexity of mainstem habitat has proved difficult, particularly when using large wood, a material that will float. As channel size increases (i.e., >10 m bankfull width), structure failure rate increases (Roni et al. 2002). However, developing effective techniques for restoring complex habitat conditions in larger channels may be necessary to recover anadromous fish populations in the Pacific Northwest.

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Buried Live Wood and Root Systems of Riparian Black Poplar

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Abstract

Wood processes in river channels are cyclical and intertwined with riparian forest community dynamics, with riparian root systems affecting bank and tree stability, failure and entrainment. The dynamics of many riparian trees, including black poplar, and the large quantities of in-channel wood they provide are strongly influenced by resprouting from fluvially-transported wood pieces, and yet little is known about their sub-aerial structures or how resprouting from deposited wood translates into the forms observed both above- and below-ground. By taking advantage of partly exposed root systems of black poplar on an island-braided river, this study uncovers the structure of within-bank live wood and root distributions, shedding light on the often complex history of their development.

Detailed 3D models of excavated structures reflect conserved, hereditary influences and the external forcing of fluvial sediment dynamics and other environmental factors. Quantitative analysis of root distributions shows that this riparian species is particularly deeply rooted, and plasticity in the root systems appears to occur at different depths between drier and wetter sites. The findings have wide implications for predicting and understanding dynamics of riparian vegetation, wood and fluvial landforms in naturally-functioning systems, and where resprouting species are used in bioengineering.

Keywords: *Root distribution; Populus; Bank erosion; Riparian vegetation; Biogeomorphology, Resprouting*

Introduction

Wood in rivers is the terminal phase of a process of riparian tree recruitment, growth, competition, senescence and entrainment (Collins et al., 2012). Tree below-ground biomass influences all stages of this process, yet remains under-investigated. By reducing erosion and mass failure of banks and anchoring trees, roots control the wood supply to river channels. Coarse root structures attached to in-channel wood also affect its deposition and retention (Bertoldi et al., 2014), and its sediment- and wood-trapping potential. Sub-aerial plant development is also fundamental to riparian ecosystem functioning and the development of the riparian plant community. In these ways riparian tree root systems influence the composition, quantity and many other properties of the wood which finds its way into channels. Transported species in many fluvial systems are adapted to regenerate upon deposition, and so tree and wood dynamics are cyclical: patterns of live wood deposition and burial influence the development of root systems, the persistence of vegetated fluvial landforms and the reinforcement of sediments.

While many of the above-ground components of this biogeomorphological cycling are reasonably well characterized, and the root growth and anchorage of riparian seedlings and cuttings has been studied, there is little information on root systems of mature vegetation in a natural riparian context. This study represents a first step in describing and understanding the distribution and structure of below-ground riparian tree biomass, with a particular focus on the impact of burial and re-sprouting on the overall rooting pattern.

Study Area

The gravel-bed, island-braided Tagliamento River in northeast Italy exhibits rapid turnover of its riparian forest and islands (Tockner et al., 2003), and has been the subject of many studies of large wood dynamics (e.g. Gurnell and Petts, 2006). Woody vegetation in the middle reaches investigated here is dominated by *Populus nigra* L. (black poplar) and *Salix* (willow) species, which readily regenerate from transported fragments. Sites covering a range of effective precipitation and groundwater availability were studied.

Materials and Methods

At recently eroded steep bank sites with black poplar, buried structures of living trees were excavated and, additionally, roots and sediments were sampled from 25 vertical profiles to a maximum of 2.4 m depth. Buried structures were mapped using structure from motion (SfM) photogrammetry and samples from key nodes of excavated wood structures were taken for dendrochronological analysis. Depth profiles were generated of root numbers and sectional area, with supporting data on sediment size, organic matter content, moisture content and fungal hyphal length density. The development of buried structures was interpreted from the dendrochronology, in relation to channel changes evident from aerial imagery and flow records.

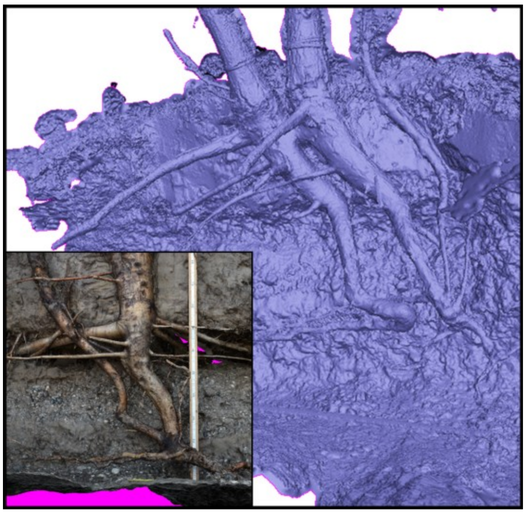

Figure 1: SfM models of buried live poplar structures down to ~ 1.7 m. Inset is a colour-shaded model. Flow direction is right to left.

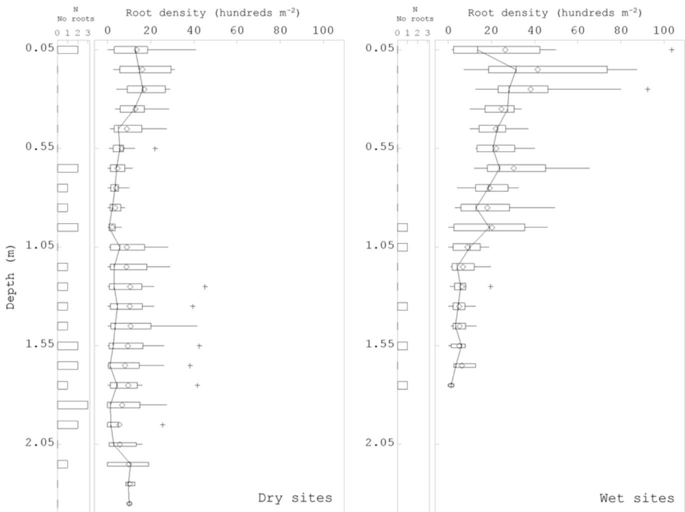

Figure 2: Variability of riparian root density with depth at drier (left) and wetter (right) sites. Mean and outlier symbols overlaid on interquartile range boxes linked by median density line.

Results

Gross sub-aerial poplar structures vary greatly, but shared some common features such as directionality related to river flow direction in their multi-stemmed form and strong leeward adventitious roots developed in fine material and often weakly grafted to form planar ‘webs’. SfM models record these coarse structures particularly effectively (**Figure 1**). Sediment surface aggradation leads to a significant proportion of wood biomass in these buried structures, with wood of diameter > 25 cm observed below 5 m from the ground surface in some cases. Linking wood structural observations with sediment profile properties and information from dendrochronological analysis and flow records, it is possible to determine the types of flood events and local conditions that lead to the deposition and survival of live wood fragments.

Finer root systems that develop after establishment are not effectively described by a simple depth decline model (particularly in terms of reinforcing root area ratio in bank sections), and show marked differences locally and between sites with differing water availability. Overall, rooting at wetter sites tends to be both better developed and more variable at shallower depths, whereas there is more investment and plasticity in deeper layers at sites more prone to water stress (**Figure 2**). Variations in root diameter with depth are more complex at drier sites. Very fine roots (< 0.1 mm diameter) dominate in terms of numbers, but globally, most root sectional area is due to roots in the range 10 – 25 mm diameter.

Discussion and Conclusions

These novel observations of the below-ground component of the fluvial large wood cycle indicate its significant scale, variability and main conserved features. Firstly, the observed riparian system is deep-rooted compared to other biomes (Schenk and Jackson, 2002), with obvious implications for bank erosion and wood supply. On the Tagliamento and similar systems with high rates of floodplain aggradation, buried stems could represent an important and hitherto underestimated source of in-channel wood for which SfM models could be a useful biomass assessment tool. The deep root systems supported by the survival of subterranean wood in the Salicaceae, and their sediment-reinforcement effect, may represent a positive feed-forward on floodplain accretion, adding further support for such riparian species being 'terrestrialising' ecosystem engineers (Gurnell, 2014, Corenblit et al., 2014).

Poplars are not anchored uniformly throughout their rhizosphere, however. Two other important 'dimensions' of rooting, besides vertical (or leaning) buried stems, are extensive webs of horizontal adventitious roots and more limited, exploratory, principally phreatophytic roots below the depth at which the tree established. The former are unevenly distributed within fine sediment floodplain layers, and the latter exist typically within stony, buried bar sediments. Consequently, the nature of root-reinforcement and thus the failure reduction of these two contrasting bank materials (fine vs. stony) is starkly different, as is tree anchorage and the likelihood of wood recruitment. Finally, this study identifies water availability as a major contributing factor to the nature and predictability of root distributions. The root profiles suggest more plastic, 'foraging' root development in upper soil layers at wetter sites, but deeper and more tightly controlled plasticity in root activity in deeper zones at drier sites.

Overall, it is clear that this multifaceted underground realm needs to be incorporated in fluvial wood dynamics, and it presents a fascinating window into the complex history of riparian forest turnover, regeneration and biogeomorphological coevolution.

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Small-scale simulations on the rule of the forest against debris flow

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Abstract

The runout prediction is a key factor in debris-flows hazard assessment. Despite its importance, few literature studies can be found about the forest capacity in reducing debris-flows mobility in the depositional zones. For this reason, the aim of this research is to explore the forest capacity to reduce debris-flows runout through small-scale experiments, in order to provide guidelines for the management of the protection forests. The laboratory investigations were conducted using the flume of the Department of Agricultural Engineering (University of Milan). A geometric scale of 1:50 was defined for the laboratory model construction. Three scenarios were simulated: no elements (i.e. without vegetation), high forest, and coppice. High forest was simulated using rigid steel screws, while coppice was simulated with flexible wicker. Elements on the depositional plane caused changes in the deposit shapes; in general, shorter runouts, and larger deposit widths were measured. The observation of debris-flow mobility suggests that high forest management is not able to offer a very significant contribution in reduction of debris flow motion for the highest sediment concentrations; instead, coppice seems able to offer a remarkable contribution, which increases for the debris flow with highest solid concentration.

Keywords: *debris flow; forest protection; small-scale experiment; forest management.*

Introduction

The prediction of runout characteristics (including runout distance, area, and width) is a key factor for hazard assessment in mountain areas (e.g. Fell *et al.*, 2008). It is widely recognized that the presence of forest can prevent slope failures and debris-flow generation for events of small/medium size by reinforcing soil through root strength (e.g. Nonoda *et al.*, 1994), suppressing debris-flow movement, and promoting debris flow deposition by the resistance provided by trunks and branches (e.g. Mizuyama *et al.*, 1989). The ratio between the height lost and the distance travelled by the centre of mass of landslides (*H/L*) is often used as an indicator of debris flows mobility in empirical methods, which have been developed to predict runout and inundation areas (e.g. Rickenmann, 2005). The capacity of forest to suppress sediment movement has been studied by some Authors trough field survey (e.g. Ishikawa *et al.*, 2003), numerical models (e.g. Irasawa *et al.*, 1991), and laboratory investigations (Morlotti, 2010). There are, instead, few literature studies about the aptitude of forest buffer to reduce debris-flows movement on the fan.

The aim of this research is to explore the ability of the forest to reduce debris-flows mobility through small-scale laboratory experiments, in order to provide guidelines on the protection forests management.

Materials and Methods

A series of laboratory experiments were performed using a small-scale flume 200 cm long, 15 cm wide, and 40 cm deep, which can be set at different slopes (15° to 45°). At the upper end of the flume, there is a tank for the mixture accumulation, whereas a runout area with an adjustable inclination (0° to 10°) is located at the toe of the experimental channel for the observations of the deposit characteristics. On the depositional plane, some threaded holes (10 cm grid spaced) allow placing vertical elements to simulate the presence of the trees. The experimental mixtures were obtained mixing water with a dry solid material sampled in real debris flow deposits, which occurred along Gadria creek (Silandro, Bz) in 2014, sieved at 19 mm. In each experiment the granular material was weighed, and mixed with water to obtain 4000 cm^3 of mixture. The inclination of the flume was set equal to 20° for the channel (S_c), and equal to 3° for the depositional area (S_d); these parameters were kept constant in each test. The interaction between the flow in motion and the elements were examined using mixtures with four different sediment volume concentrations (C_V): 0.50, 0.55, 0.60, and 0.65. Three different scenarios have been finally set in order to explore the forest management effects on debris-flow depositional behaviour: 1) free depositional plan (i.e. without elements), 2) presence of rigid elements on the depositional plane to simulate high forest, 3) presence of groups of flexible elements on the depositional plane to simulate coppice. A geometric scale was defined for the laboratory model with a scale factor of approximately 1:50. The high forest scenario was simulated using rigid steel screws 10 cm long and with a diameter of 0.6 cm. Aiming to model the shoot flexibility, the coppice scenario was simulated using for each stump 8 pieces of wicker 6-8 cm long, and of 0.2 cm in diameter. The elements allowed to simulate real forests with a density of 400 stands per hectare, with stand diameter of 0.30 m for the high forest case (basal area equal to 28 m^2ha^{-1}) and 0.10 m for coppice (basal area equal to 25 m^2ha^{-1}). At the end of each test, the following geometric characteristics of the deposit have been collected: a) maximum length reached by the debris flow (runout, R); b) maximum width (W); c) maximum deposit thickness (s_{max}); d) weight of deposited material (P_{dep}); e) weight of remained material in the tank (P_{ret}).

Results

A total of 29 tests were carried out and the geometric characteristics of the deposit were measured. Runout (R) ranged from 37.0 to 119.0 cm, maximum width (W) ranged from 34.0 to 52.0 cm, maximum deposit thickness (s_{max}) from 0.60 to 3.30 cm, deposited area (A) from 1450 to 4730 cm^2 and travel angle (equal to the arctangent of H/L ratio) from 15.40° to 19.56°. As shown by the box and whiskers plots (Figure 1) the main geometric features change over the three scenarios. R decreases from the no elements condition, to high forest, to coppice scenarios, while s_{max} and H/L show an increasing trend. W, instead, seems to be not affected by the presence of elements on the depositional plane.

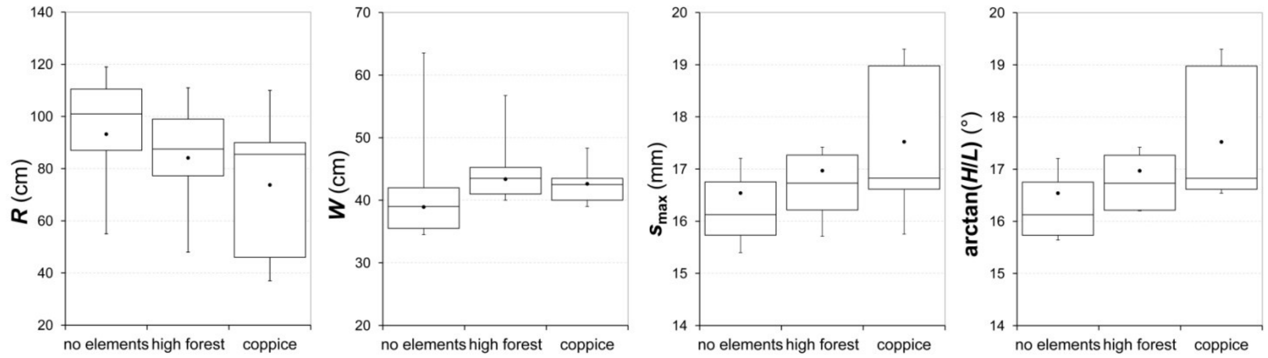

Figure 1: box plots of the geometric features for the three scenarios (no elements, high forest and coppice; samples size 13, 8, and 8 respectively): runout R, maximum width W, maximum deposit thickness s_{max}, and travel angle (equal to the arc tangent of the ratio H/L).

The reduction of R, in the cases of the presence of trees respect to the no elements scenario, ranged from 15.0% (C_V = 0.50) to 2.2 % (C_V = 0.65) in high forest scenario, and from 13.9% (C_V = 0.50) to 16.5% (C_V = 0.65) in coppice scenario. The increase of the H/L ratio was analysed in terms of its excess passing from presence of elements to the no elements scenario. In high forest scenario, H/L excess ranged from 4.9% (C_V = 0.50) to 1.0% (C_V = 0.65), and from 4.5% (C_V = 0.50) to 7.6% (C_V = 0.65) in coppice. The Mann-Whitney U

test (level of significance 0.10) was then performed to check if significant differences exist between the depositional sizes of paired scenarios. Results showed the coppice statistically differs from no element scenario for all the analysed variables (R, W, s_{max}, H/L), whereas the high forest presented differences only in deposit width and thickness when compared with the no element scenario. Only coppice, then, seems to be able to significantly affect the debris-flow mobility at the depositional stage.

Discussions and Conclusions

Our small-scale debris flow showed that the presence of vegetation elements on the fan area causes changes in the deposit shape. In general, shorter runouts, and larger deposit widths have been observed.

Our observations on debris flow mobility suggest that high forest management is not able to significantly contribute to reduce debris flow motion at the highest solid concentrations, while a certain reduction can be achieved for the lowest concentrations. On the contrary, coppice seems to provide a notable contribution, which increases as the solid concentration raises. At the lowest concentration, high forest offered an *H/L* excess increment, if compared to no element scenario, 1.1 times greater than coppice, while at the highest sediment concentration, coppice offered an increment of *H/L* excess 8.1 times greater than high forest. The same behaviour can be observed for *R* reduction: at the lowest concentration, high forest and coppice showed a similar reduction capacity of *R* with respect to no element scenario, whereas at the highest concentration, coppice offered a reduction of *R* values 16.5 times greater than high forest.

Our interpretation of the better protective function exhibited by coppice setting is that coppice stocks manifest a more effective obstruction action compared to high forest trunks. In fact, the coppices in our laboratory model were composed by eight elements (coppice shoots) and occupied in the merging zone (coppice stocks) about 1 cm transverse to the flow direction, whereas high forest trunks occupied 0.6 cm per element. In addition, at the higher concentration of the mixtures, largest particles floating in the matrix are easily trapped by the upper part of the simulated coppice forests, where the shots form a sort of retaining rake. At lower concentrations, such an effect is reduced because both low flow depths do not interact with the ‘rake’ and the debris-flow tail exerts a washout effect against the sediments previously deposited behind the elements. This fact explains the highest variability of *R* and *H*/*L* in the coppice data.

To consolidate such findings, more work is needed to further investigate the validity of using the *H/L* ratio as a valid indicator for different soil uses and vegetation covers of the fan area as well as to draw guidelines on the protection efficiency of the forest against gravity-driven natural hazards.

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Retracing wood dynamics during an extreme flood event in South Tyrol, Italy

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Abstract

A severe meteorological event occurred on August 4th and 5th 2012 and triggered a chain of processes along the Isarco River and its tributaries in South Tyrol, Italy. Sediment transport processes and complex wood dynamics damaged road and railway networks, bridges, embankments and open check dams. In this work we present the documentation of wood dynamics both in qualitative and quantitative terms and illustrate the adopted methodological approach. With respect to methodology we first identified, within the entire process area, different transport systems with distinctive wood transport behaviors; we then reconstructed the hydrological event based on the process-knowledge gathered in post-event field documentation activities. Understanding wood dynamics during extreme flood events is an important factor for the implementation of effective risk mitigation strategies.

Keywords: *wood transport; floods; risk management*

Event overview

An extreme meteorological event, occurred on August 4th and 5th 2012, affected the Upper Isarco River Basin between Colle Isarco and Fortezza, South Tyrol, Italy (compare Fig. 1 – upper part). An accurate statistical analysis of the rainfall event (Borga, unpublished) revealed that large recurrence intervals corresponded to rainfall durations of 6 hours (R.I. between 200 and 300 years) and comparably low recurrence intervals (R.I. of approx. 20 years) could be associated to shorter (1 hour) and longer (24 hours) durations. The same study concluded that, from a spatial perspective, rainfall intensities were most severe for the orographic left part of the Vizze basin. Debris flow and bedload transport processes were triggered along the stream network (compare Fig. 1 – lower right part). As described in detail in the next section, all relevant stream processes were characterized by accentuated wood transport rates. In Fig. 1 (lower left part) we report, for each documented stream process, the associated deposited wood volumes.

Reconstructing wood dynamics

We first identified within the entire process area four boundary elements with distinctive differential wood transport behavior (compare Fig. 2 central part): 1 – road embankment (Vizze River Basin, middle course), 2 – hydropower dam (Vizze River Basin, middle course), 3 – bridge crossing (Vizze River reach close to the confluence with the Isarco River), 4 – hydropower reservoir and dam (along the Isarco River in Fortezza).

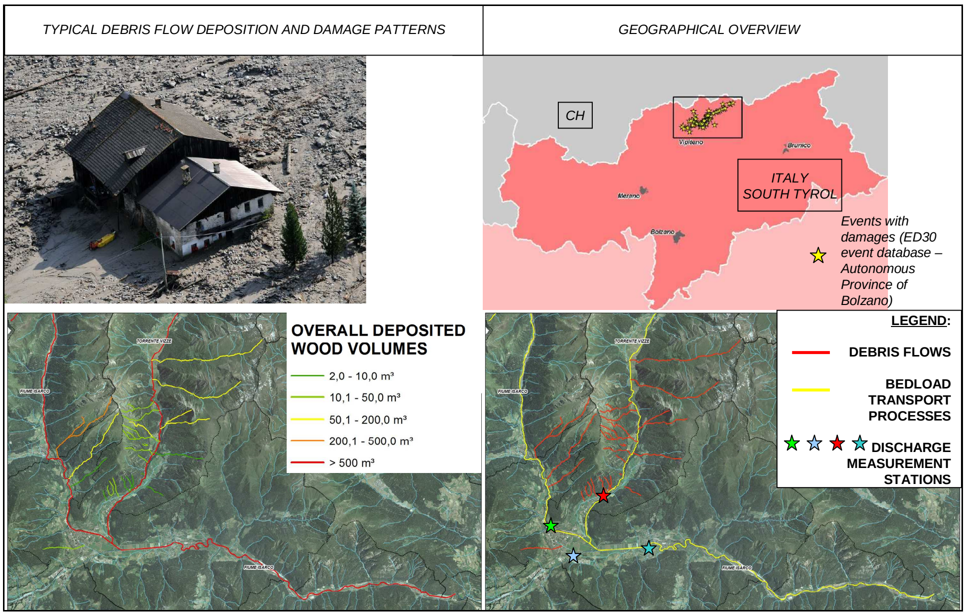

Figure 1: Upper part: Typical debris flow deposition and damage patterns (left) and geographical overview (right); Lower part: documented deposited wood volumes (left) and leading processes and location of measurement stations (right).

Event documentation highlighted that the boundary elements 1, 2 and 4 completely entrapped approaching wood material, whereas boundary element 3 featured a switching behavior. According to reconstructions made by the fire brigades, no entrapment was detected before 1:30 AM of August 5th, and then a sudden clogging process through wood material followed. Later, only negligible wood volumes were released to the downstream system. By analyzing post-event field documentation and by taking into consideration the constraints on wood dynamics at the identified boundary elements, we could retrace wood transport dynamics from a spatial perspective (compare Tab. 1 and Figure 2 for details).

System name	Id	Type	Description
Grossbergbach	1a	RTD-(***E***)	closed system, with recruitment - R, transport - T, deposition -D and entrapment processes at the boundary element ***(E)***
Burgum creek	1b	RTD-(***E***)	closed system, with recruitment - R, transport - T, deposition -D and entrapment processes at the boundary element ***(E)***
Upper Vizze	2a	RTD-(***E***)	closed system, with recruitment - R, transport - T, deposition -D and entrapment processes at the boundary element ***(E)***
Lower Vizze	3a	RTD-(***FE***)	temporally open system with flowthrough ***(F)*** until a clogging process at the boundary element occurs
Isarco	4a	RTD-(***F***) -TD-(***E***)	spatially open system - wood flowthrough ***(F)*** from a feeding system (3a), whereas the system is closed at the downstream end ***(F)***
Viedalmbach	4b	RTD	closed system, with recruitment - R, transport - T, deposition -D, negligible flowthrough
Langstaudenbach	4c	RTD	closed system, with recruitment - R, transport - T, deposition -D, negligible flowthrough
Überwasserbach	5a	RTD- (***F***)	open system, with recruitment - R, transport - T, deposition -D and flowthrough processes ***(F)*** to the receiving system

Table 1: Wood dynamics system structure. Letters in beckets refer to wood behavior at boundary elements. Letters without brackets indicate wood recruitment transport and deposition processes (compare for details Fig. 2)

Conclusions and Outlook

Through the adopted event documentation procedure we could retrace wood dynamics during the considered extreme event. Relevant wood recruitment, transport, deposition processes along the stream network could be localized and approximately quantified. Specific behaviors ad system boundary elements could be identified.

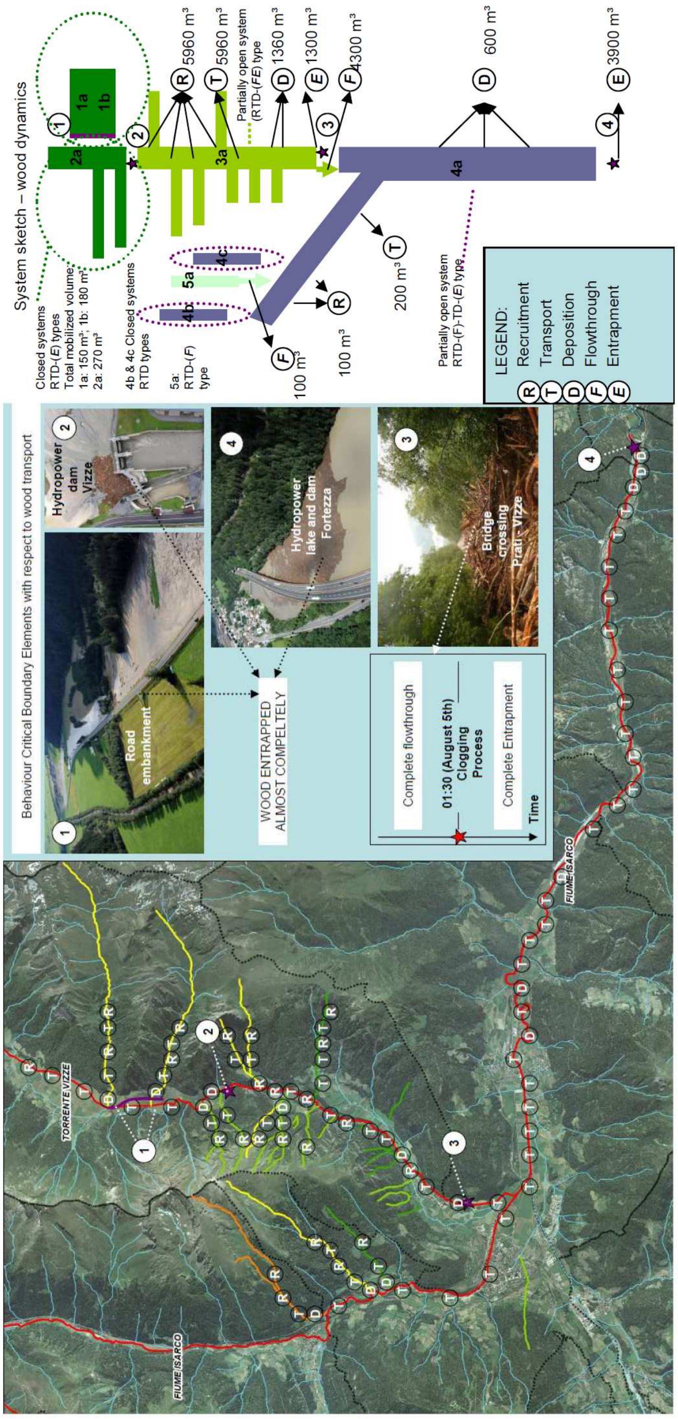

Figure 2: Retracement of wood dynamics: qualitative dynamics along the stream network (lower part), specific behavior ant boundary elements (central part) and wood budget in a system view (upper part)

The wood material feeding role of the Vizze creek could be better understood. As an outlook we plan to numerically simulate wood dynamics by advanced modeling techniques (Mazzorana et al., 2010; Ruiz Villanueva et al., 2014). Understanding wood dynamics during extreme flood events is an important factor for the implementation of effective risk mitigation strategies (i.e. redesign of critical flow sections, retention of wood volumes and proper emergency operations). Intervening on wood stand volumes to reduce potential wood recruitment has to be judged carefully. The regenerative nature of wood on the one hand and its abundance on the other hand might affect the overall mitigation result.

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Monitoring of large wood supply and transport in Polish Carpathian watercourses

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Abstract

In order to determine parameters indicating the potential for wood recruitment, mobility and the residence time of in-channel wood, we used several methods for wood monitoring in two exemplary Polish Carpathian watercourses of different size: Kamienica Stream and the Czarny Dunajec River. In the Czarny Dunajec River unpredictable nature of bank erosion caused that the majority of tagged trees on undercut river banks survived a major flood in May 2014. In contrast, the experiment with logs tagged with radio transmitters and put into the river during the passage of the flood wave provided information about the length of transport and preferential sites of large wood deposition in the wide mountain river. The long-term monitoring of trees tagged with metal plates demonstrated that in the period without a significant flood, windthrow has been the main factor of wood supply to the channel of Kamienica Stream. Such investigations allow to determine the transport distance and the locations of deposition of wood pieces transported during floods and may be useful in estimating flood risks on mountain watercourses.

Keywords: *Large wood; Mountain watercourse; Wood dynamics; Flood risk*

Introduction

In addition to mineral sediments, in-channel large wood strongly influences fluvial processes (Montgomery et al., 2003). Monitoring of wood recruitment and mobility can be a useful tool not only for answering scientific questions but particularly for the assessment of flood risk that can be generated by the kinetic energy of floated wood colliding with in-channel and bank structures or elevating the level of floodwater by wood jams, especially those formed at bridge cross-sections. Such monitoring is a component of a research project on flood risk in the Tatra Mountains foreland, Polish Carpathians (Kundzewicz et al., 2014).

Study Area

We performed our studies in two Polish Carpathian watercourses:

- second- to fourth-order reach of Kamienica Stream in the Gorce Mountains National Park. Since 1980 this stream reach has been almost free of human impact on the channel and riparian zone. In the last few years widespread bark beetle infestation greatly increased the delivery of fallen trees to the stream channel. This rises a question as to whether wood retained in the stream reach within the national park can be rapidly transported during a flood event to the downstream, urbanised valley reaches, where it can threaten bridges and near-channel infrastructure.
- fifth-order Czarny Dunajec River, along which a pronounced development of riparian forest took place in the twentieth century. The studied 17 km-long reach without significant tributaries is characterized by varied morphology and channel management. After a 7-year flood in 2001 Wyżga & Zawiejska (2005) performed a detailed wood inventory in this reach.

Materials and methods

In 2009 we started observations in Kamienica Stream, where 429 trees growing along three channel sections were tagged with numbered metal plates to allow monitoring of their recruitment to the channel, transport and storage. In each section plates of a different type of metal (steel, copper or aluminum) were installed to allow the use of a metal detector to recognize the origin of transported downstream trees, if the tagging plates are invisible or inaccessible. All studied sections have been repeatedly monitored to determine the causes and timing of wood delivery or transport after any extreme weather event (flood, strong wind or snowfall). We also performed here a detailed inventory of large wood deposits retained on 7 km of stream length. The recorded pattern of wood distribution in the stream was subsequently compared to the pattern of morphometric parameters of the channel, including width (Wyżga et al., 2015).

As the Czarny Dunajec is considerably wider than Kamienica Stream, radio telemetry was applied for monitoring wood mobility during floods in this river. In spring 2014, 50 trees growing close to undercut channel banks were tagged with radio transmitters of unique signal frequency. During a major flood in May 2014, 30 logs of 3 m length were also put into the river at the beginning of three river sections with different morphology. After the flood the logs and relocated trees were searched using antennas and signal receivers.

Preliminary results

No significant flood occurred in Kamienica Stream during 5 years of observations. We noted 23 trees fallen to the channel as a result of windthrow (14 trees), snow overloading (4 trees) and bank erosion (5 trees) (Fig. 1). The high efficiency of windthrow as a mechanism of large wood delivery reflects the fact that the majority of spruce trees in the riparian area are affected by bark beetle that makes them more susceptible to the wind (cf. Brag, 2000). Trees delivered to the channel were either not transported by the stream, or moved only short distances, not exceeding 100 m. As the metal plates fixed to the trees are numbered, we can determine the distance of tree transfer, from its original position on the stream bank or the former position within the channel.

Figure 1: An example of beech tree fallen to the channel of Kamienica Stream. The white arrow indicates a metal plate with a number allowing to identify the original location of the tree and the length of its transport in the stream.

Remote tracking is a very promising method of monitoring pieces of wood transported during floods (MacVicar et al., 2009), but so far it has been rarely used. Radio transmitters in the studied reach of the Czarny Dunajec River were installed only in the trees considered to be the most vulnerable to erosion. In May 2014 a 20-year flood occurred on the river. However, most of the tagged trees survived the flood because river banks were often eroded at random locations. More promising results were obtained in the experiment with tagged logs that were put to the river during the passage of the flood. The experiment proved that in the wide river, pieces of wood can be transported during a flood on distances up to a dozen kilometres and are mostly deposited in wide, multi-thread channel sections.

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Observations of in-stream large wood displacement in Chilean mountain channels

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Abstract

In stream large wood (LW) displacement was been studied over several time periods in channel segments of four low-order mountain streams, southern Chile. Wood pieces with more than 10 cm in diameter and 1 m in length found within the bankfull channel were measured and their position was referenced, and 31% of logs found in the study segments were tagged to investigate log mobility and travel distance. All channel segments were first surveyed in summer and then after consecutive rainy winter periods. LW mean and maximum travel distances per annual period were not significantly different between periods with flows exceeding and with flows less than bankfull stage. For a range of absolute and relative piece diameters and lengths, LW mean and maximum travel distances were in general not statistically different between annual periods where maximum water level exceeded or not channel bankfull depth. However, travel distance of wood pieces for every annual study period was significantly correlated ($P \leq 0.05$) with $H_{15\%}$, the level above which the flow remains for 15% of the time (Fig. 1). These results contribute to understanding the complexity of wood dynamics in LW dominated mountain rivers.

Keywords: *Large wood; Travel distance; Mountain rivers; Chile.*

Introduction

The morphologic and ecologic significance of in-stream large wood (LW) on stream ecosystems are widely recognized, but although LW loading and downstream mobilization can increase the associated hazard of floods, wood entrainment and transport have received relatively less research attention (Braudrick & Grant, 2000; Schenk et at., 2013). The ratios of piece length and diameter to bankfull channel width and depth are commonly adopted to predict wood mobility, while wood dynamics is highly dependent on the flow regime and channel slope (Lienkaemper & Swanson, 1987; Gurnell et al., 2002). LW moves farther and more frequently in large (> fifth order) than small streams, smaller pieces move farther than larger pieces and piece diameter strongly influences depth of flow required to entrain and transport logs, thereby influencing distance their displacement length (Lienkaemper & Swanson, 1987; Abbe et al., 1993; Martin and Benda, 2001; Braudrick and Grant, 2000). Individual logs from jams that are removed can be transported several kilometers downstream suggesting that removal of a logjam creates a pulse of transport, and the locations wood jams can reduce movement distances for LW of all sizes (Braudrick & Grant, 2001; Wohl, 2011).

The objectives of this study were (a) to quantify annual large wood mobilization and measure transport distances, and (b) to explore potential relationships between transport distance with dimensions of moved wood pieces and discharge features. The analysis covers several time periods in four catchments in southern

Chile, and is intended to provide additional insights on the processes controlling large wood dynamics.

Study Area

The study concentrates in channel segments of the Pichún (431 ha), El Toro (1783 ha), Tres Arroyos (907 ha) and Vuelta de Zorra (587 ha) catchments, located both in the Coastal and Andes mountain ranges in southern Chile. Detailed information of these sites can be found in Iroumé et al. (2014).

Materials and Methods

Between 1 and 2.2 km-log segments of the main channels of the study catchments have been surveyed for morphologic and large wood characterization since 2005 for Tres Arroyos and since 2008 for Pichún, El Toro and Vuelta de Zorra. Channel segments were first surveyed in summer and every wood piece found within the bankfull channel with > 10 cm in diameter and > 1 m in length was measured and its position was referenced, and 31% of the LW pieces were tagged. Each segment was resurveyed after each rainy winter period, and every tagged wood piece that had moved downstream from its initial position was re-referenced to investigate log mobility and travel distance (Iroumé et al., 2014). Stream water level is monitored in the study catchments with continuous digital recorders.

Mean and maximum travel distances were compared (*t*-tests) between periods where maximum water level (H_{max}) was higher and lower than bankfull stage (H_{Bk}). Stepwise regressions were used to examine relationships between mean and maximum travel distances as dependent variables and stream water level characteristics during each annual period (H_{max}, H_{Bk} and $H_{X\%}$, the level above which the flow remains for X% of the time) as independent variables. Variables were t-tested for normality or otherwise log10 transformed. Regressions and differences were considered statistically significant if $P \leq 0.05$. The SAS (version 9.1) statistical software package was used.

Results

LW mean and maximum travel distances per annual period were not significantly different between periods with flows exceeding and with flows less than bankfull stage. Mean and median travel distances of mobilized LW were 240 and 314 m for periods with $H_{max} \leq H_{Bk}$ and 308 and 231 m when $H_{max} > H_{Bk}$, and for LW maximum annual travel distances, mean and median travel distances of mobilized LW were 885 and 898 m for periods with $H_{max} \leq H_{Bk}$ and 969 and 944 m when $H_{max} > H_{Bk}$.

For a range of absolute and relative piece diameters (D_{log}, < 20 cm, 20 - 40 cm and > 40 cm; D_{log}/H_{Bk}, < 0.5, 0.5 – 1.0 and > 1.0) and lengths (L_{log}, < 4 m, 4 – 7 m and > 7 m; L_{log}/W_{Bk}, < 0.5, 05 – 1.0, > 1.0), LW mean and maximum travel distances were in general not statistically differents between annual periods where maximum water level exceeded or not channel bankfull depth.

Statistically non-significant trends were observed between LW traveled distance and piece diameter/bankfull depth ratio as independent variable and between travel distance/piece diameter with element length/mean bankfull width. LW traveled distance/piece diameter ratio decreased with increasing piece length/mean bankfull width ratio.

Mean travel distance of wood pieces for every annual study period was significantly correlated ($P \leq 0.05$) with $H_{15\%}$, the level above which the flow remains for 15% of the time (Fig. 1).

Discussions and Conclusions

LW travel distances were highly variable for the individual pieces and for the different study periods and streams. However, transport distances appear higher than those reported by Martin & Benda (2001), especially for smaller channels such as Pichun.

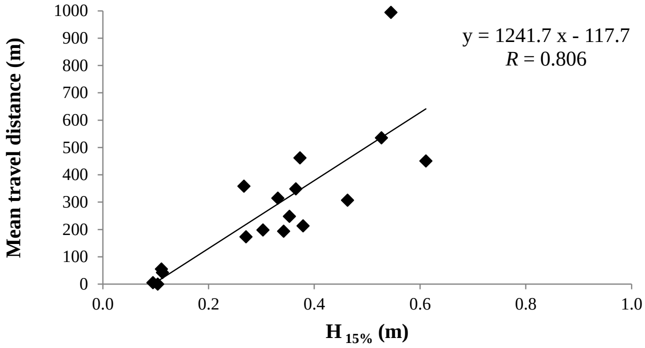

Figure 1: Relationship between mean LW travel distance and $H_{15\%}$.

Mean and maximum travel distances per annual period were not significantly different between periods with flows exceeding and with flows less than bankfull stage. This can be a consequence of the relatively normal maximum flows registered during the study (return periods ≤ 5 years) but also to the presence of logjams that can reduce LW movement distances (Wohl & Goode, 2008; Curran 2010). Mean and maximum travel distances of wood pieces in the different annual study periods were significantly correlated ($P \leq 0.05$) with $H_{15\%}$ (the level above which the flow remains for 15% of the time during each annual study period), indicating that not only high flows but also the time above which these flow remains during the year are important to explain distance traveled.

Although Abbe et al. (1993) and Braudrick & Grant (2000) reported a strong dependence of piece diameter on entrainment and that distance traveled significantly related to the ratio of piece length to channel width, we did not find any significant trend between LW traveled distance and piece diameter/bankfull depth ratio.

This study contributes to shed light on processes of large wood entrainment and transport in high-gradient mountain streams, which are still relatively less studied than large rivers.

Acknowledgments

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Challenges of numerical modelling of flow, sediment and wood in rivers

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Keywords: *Numerical Modelling of Wood transport, Challenges in River Dynamics Numerical Modelling.*

Introduction

The progress of models in the field of geomorphology are well documented (Hardy, 2013). Models, both conceptual and numerical, are identified as an alternative or comparable research methodology to physical modelling and field-based measurements. Regarding fluvial processes, fluid flow and sediment transport models have been developed and extensively used during the last decades (Merrit et al., 2003); however, modelling of wood is still quite immature. Since the works from Braudrick and Grant (2000), providing the basic framework to approach wood motion modelling, several attempts have been made to combine wood transport and numerical models (Mazzorana et al., 2010; Merten et al. 2010; Comiti et al., 2012; Hafs et al., 2014), however, there was not so far any model able to couple the three components of most forested fluvial corridors.

The numerical model presented by Ruiz-Villanueva et al. (2014) tried to do this. The approach is based on a deterministic model proposed to simulate the transport of multiple wood elements (assuming logs as cylinders) of different sizes under complex hydraulic conditions at short timescales and fully coupled to the hydrodynamics (Bladé et al., 2014). Keeping the approach as simple and robust as possible, while retaining the key elements for the description of the feedbacks between wood and hydromorphodynamics, the model describes the initial motion and movement of logs including two possible transport mechanisms (i.e. floating or sliding), and simulating interactions between logs and the channel configuration (including infrastructures) and among logs themselves. The coupling of wood transport and hydrodynamics was solved by including drag forces in the governing flow equations as an additional shear stress term in the 2D Saint Venant equations, similar to roughness.

In this work we explore the ability of the proposed 2D model to reproduce the observed interactions between large wood and river hydromorphology and discuss some remaining challenges.

Modelling wood and model parametrization

With the mentioned 2D model of Ruiz-Villanueva et al. (2014), based on the finite volume method, when logs are placed in the modelling domain, the incipient motion is determined by the balance of forces acting on the center mass of the log. Once the log is put in motion, two possible transport mechanisms are implemented, sliding on the river bed, or floating. In all cases, translation and rotation are considered depending on the velocity field at the two ends of the log. When the piece of wood is moving sliding its velocity will be very different from the flow velocity, with friction as the main control factor of movement. If the log is floating, its velocity will be the same as the flow velocity, unless turbulence is considered. Turbulent fluctuations of velocity affect wood, introducing a random component into the motion of logs. The presence of wood reduces the available storage volume at every finite volume and adds a new shear stress (produced by the drag force of the logs) term in the Saint Venant equations. In addition, logs velocity and movement can also be modified when interactions with the river geometry or between logs themselves occur.

The numerical model needs initial and boundary conditions for wood. The initial position of each log (x, y coordinates of the mass center and angle with respect to the flow), its length, diameter and wood density for the initial time step should be provided. Moreover, inlet boundary conditions (i.e. logs entering the simulation) can also be assigned to the simulation domain boundaries, specifying a number of wood pieces per minute and its characteristics. A recent updating of the model allows to set several inlets, meaning that not just wood recruitment form upstream is possible, but along the riversides, due to bank erosion, or tributaries. Based on a detailed knowledge of the fluvial corridor, riparian vegetation, and wood availability, ranges of the main characteristics of logs need to be established: maximum and minimum lengths, diameters and density of wood. Every inlet boundary could have different ranges, if the recruited wood has different characteristic (different species, different ages, etc.). Stochastic variations of these parameters together with position and angle are used to characterize the wood rate entering the domain.

Interactions between flow and wood

In-stream wood affects the flow field, in general determining an increase in roughness and altering the characteristics of turbulence (Gippel, 1995). This effect of wood on the hydrodynamics is represented by the numerical model, as was observed in the study of the confluence of two mountain rivers in the Spanish Pyrenees: Cinca and Barrosa Rivers, close to the village of Bielsa (Figure 1).

Interactions between wood and morphodynamics

The presence of in-stream wood could be associated to sediment deposition, bank stabilization and creation of new landforms, controlling the river planform style (Eaton et al., 2010; Davies and Gibling, 2011; Bertoldi et al., 2014). In the same case mentioned above, Figure 1 also shows the evolution of critical diameter, obtained with the Shields criteria, in the two rivers confluence, including wood and without wood in the numerical model. The effect of wood drastically decreased the critical diameter, and thus the bedload transport capacity. At present standard expressions have been used for sediment transport prediction, but some more knowledge on some process, like the influence of logs on skin friction, and form drag is needed.

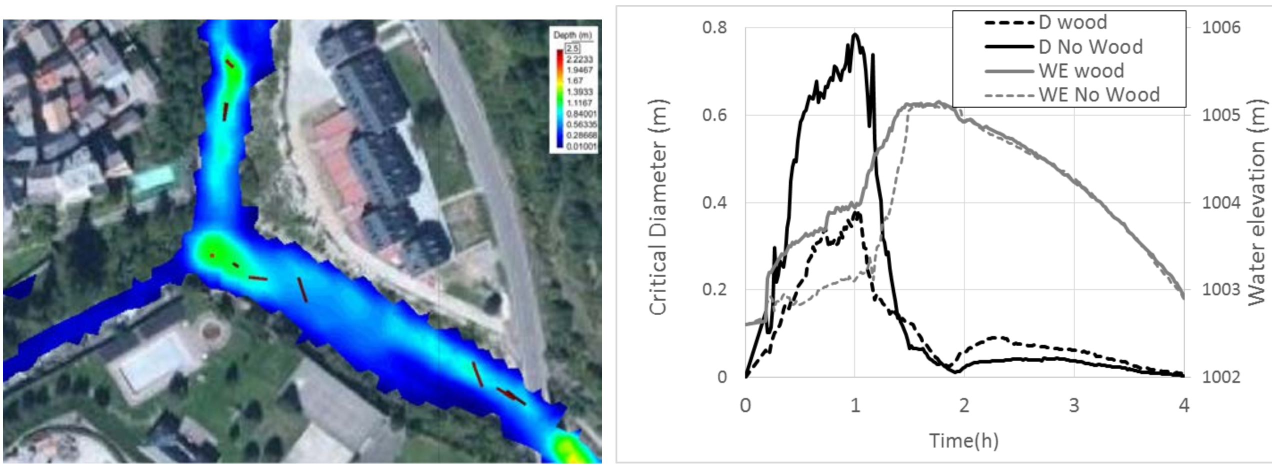

Figure 1: Effect of wood transport on water depth evolution in a confluence. Left: a detail of the numerical model with some logs. Right: water elevation evolution and evolution of critical diameter in the confluence with two different hypothesis: presence of wood transport in Barrosa river or not. The effect of wood transport is observed only in the rising phase of the flood because of a delay in the incoming hydrographs and the lack of logs in Cinca River (coming from the west) as the study area is immediately downstream of a dam.

Discussions and Conclusions

Numerical modelling proved powerful to have the possibility to signal out the effect of different parameters, which is difficult to perform with field data. Numerical modelling is an effective tool that allows studying flow, sediment, and wood dynamics in a controlled environment and opens new possibilities for understanding and disentangling the complex linkages in the hydromorphological evolution of the fluvial system. Although several constraints could be mentioned. The main limitation is to get enough field-data to properly set boundary conditions and to validate results. On important challenge of model testing lies in the development of a set of elementary validation cases, or benchmarking. Extensive model validation is crucial for future studies combining physical and numerical modelling, which is a common practice for other river dynamics processes. Although the described numerical model was verified in a flume (in terms of evaluation of the model performance), no real river prototypes have been combined with numerical models so far to analyse interactions between flow, sediment and wood. A remaining challenge is developing models which reproduce more accurately the complex shape of wood pieces, logs with root wads, for example; or the complex process interactions occurring in the fluvial ecosystem.

Besides these limitations, numerical modelling allows for the investigation of the role of different controlling parameters, guiding future field observations. Models open the possibility to predict results of restoration projects, by testing scenarios. And they may help in the evaluation of the potential hazards and risks at critical sections, such as bridges.

However, being aware that after decades of modelling sediment transport in rivers, knowledge is far from completed, there is still a long way and promising challenges to endeavor in regards to wood transport, even more for combining both processes.

Acknowledgments: Many people made this work possible, including a good number of researches and staff from Flumen Institute and from University of Bern.

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Wood responding to and driving hydromorphologic complexity in the near-natural River Sense (Switzerland)

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Abstract

The River Sense represents one of the last unregulated rivers in Switzerland where only about 10 % of all streams remain in a natural or near natural state. Therefore, the Sense provides an opportunity to investigate interactions between hydrology, geomorphology, and ecology. In this paper we will present the analysis of the interaction between large wood and the hydromorphological quality of the river. We observed contrasting patterns on wood dynamics in different reaches of the rivers, and these are related to the different geomorphic and hydrodynamic configurations. It is particularly important to analyze relatively unmanaged systems, which will provide a basis for comparison with rivers that have been subject to different types and intensities of management, contributing to the development of strategies for the restoration of impacted systems.

Keywords: braided river, near-natural river, hydromorphology, HMID, Sense River.

Introduction

Large wood plays a major role in structuring the geomorphological and ecological character of rivers (Montgomery et al., 2003), and particularly in relatively natural, large river-system (Gurnell et al., 2000).

As a result of widespread and intensive river management, few examples of complex, unmanaged river systems remain wide world and within Europe (Vörösmarty et al., 2010). In Switzerland, only about 10 % of all streams remain in a natural or near natural state (BAFU, 2010). The River Sense represents one of the last unregulated rivers in Switzerland where hydrographic events are driven by snowmelt and precipitation events without any power schemes or major flow diversion works. Around 23 km of the total 35 km of the main stem length of the River are mostly in a morphologically pristine status. Moreover, the riparian corridor provides home to the longest alluvial forest conserved in the country. For most of its length, the river flows through agricultural landscape, with the exception of the headwaters being characterized by a natural mountainous setting (Gostner et al., 2013a). Therefore, the Sense provides an opportunity to investigate interactions between hydrology, geomorphology, and ecology, in one of the few large braided rivers in a relatively natural setting.

The aim of this work is to analyse interactions between the presence of wood (abundance and distribution) and the geomorphic and hydrodynamic complexity of the river. The hypothesis we will test is that the river morphological configuration directly affects the presence of wood along a stem and, on the other hand, wood has an impact on the general hydromorphological quality of the river. On a wider context not only spatial but temporal analysis will be carried out. To do this, several wood inventories, maps and aerial pictures of different years will be analyzed. In addition, available data from some previous studies provided a solid basis for these analyses (Rohde, 2004; Gostner et al., 2013a).

Study Area

The River Sense is a 4th order river draining a watershed of 432 km^2 and is a tributary of the River Saane (Aare Basin; Fig.1). No water impoundments or withdrawals exist along the main course and its main tributaries; also the urbanization of the watershed is very limited, thus the hydrological regime of the stream is nearly unaltered. Also gravel extraction or addition activities are practically non-existent. Consequently, along its morphologically unaltered part the river Sense represents a water course in its reference status. However, prior to confluencing with the river Saane, the River Sense has undergone river training works of different degree over the past decades, resulting in a trapezoidal channel that has been protected by rip-rap partially on one and partially on both banks (Gostner et al., 2013a).

Figure 1: Location of the River Sense and its main tributary (Scharzwasser) in Switzerland and 4 of the 5 studies sites.

The analysis were performed in five sites (Fig.1) with contrasting morphology, flow conditions and human impacts: Site S1 is characterized by a braided system with notably active sediment transport dynamics; Site S2 is situated in an incised limestone bedrock gorge where the river Sense is flowing as a single thread channel with locally limited braiding patterns; Site S3 is similar to site S1, although some anthropogenic alterations are presents (i.e bridge, bank reinforcements); Sites S4 and S5 are flowing through a more densely urbanized setting, where the river Sense has been trained in the past to a notably altered single-thread channel.

Material and Methods

Concerning the methods and types of analysis carried out for the development of this research project, on one side they were focused on the measurement and mapping of large wood (LW) along each of the study sites, to investigate any nexus with river morphological and hydrodynamic configuration. On the other side, an analysis of both spatial and temporal hydromorphological variability was performed at all the reaches though the use the HMID (Hydro Morphological Index of Diversity), developed by Gostner et al. (2013b). Finally, from a comparison of the results obtained following these two approaches, the correlation between the presence of LW and HMID values at the study sites was investigated, both on a spatial and on a temporal scale.

Preliminary results

Preliminary results showed remarkably high variation in the quantities of stored wood among the river segments. Relatively low amount of wood was observed in Sites 4 and 5, while large quantities were found in Sites 1 and 3. In these sites the geomorphic features in which considerable quantities of wood were observed, included: (i) the heads of vegetated islands; (ii) the margins of established islands were wood was deposited as lateral ribbons; (iii) point bar crests over which the flood flow was too shallow to enable flotation of logs.

The analysis of HMID shows that the index is notably higher at the natural or nearly natural sites, while it presents reduced values in the trained reaches (S4 and S5), thus denoting a higher hydromorphological variety in the former and a rather poor heterogeneity in the latter. When investigating the phenomenon on a temporal scale, natural sites present a notable stability in the values of HMID for most part of the year, whereas the index decreases in occurrence of threshold discharges associated with the so-called bed preparation functional flows (return frequencies of approximately 1 year). On the opposite, at the regulated reaches HMID constantly decreases and there is no evident distinction of threshold events.

There is an evident correlation between HMID and wood quantities (Figure 2).

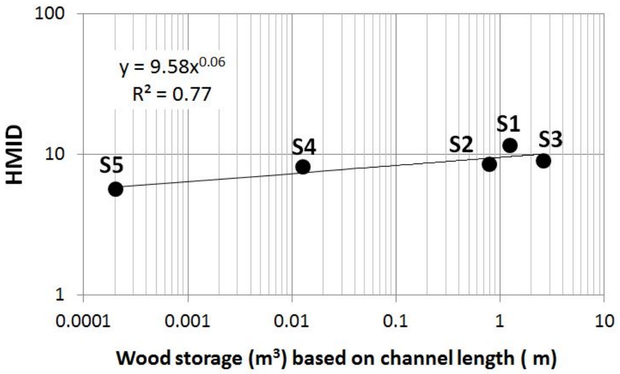

Figure 2: Relation between HMID (calculated for the median annual flow) and volume of stored wood (m^3) per reach length (m).

In reaches characterized by a high hydromorphological configuration (S1-S3) wood volumes are relevant. On the contrary, at trained reaches (S4 and S5) poor quantities of wood were surveyed and also the values of HMID are rather low. Further steps of the research will analyse the contribution given by the presence of LW to the increase of hydromorphological heterogeneity, with the possible creation of new habitats. Furthermore, the effect of the presence of LW on the temporal variability of hydraulic parameters in proximity of wood deposits will be investigated.

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Large wood transported during the exceptional flood event of 24 July 2014 in the Emme catchment (Switzerland)

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Keywords: *exceptional flood, large wood transport, large wood recruitment, wood budget, Emme River*

Introduction

Few studies have documented the effect of high magnitude floods on large wood recruitment, transport and deposition. One of the most exhaustive investigations was carried out after the August 2005 flood in Switzerland. A comprehensive event analysis was performed in several catchments to specify the transported wood volume, its origin, and main characteristics (Waldner et al., 2008; Schmocker and Weitbrecht, 2013). Another recent example of a post-flood survey is given in Lucia et al. (2015) and was conducted in the Magra river basin (Italy). Although these studies brought sound knowledge regarding wood transport during floods, many relevant questions remain open to date, namely with respect to wood dynamics and design management strategies related to wood in rivers.

The 24 July 2014 flood and the Emme river basin

During the morning of 24 July a severe thunderstorm hit the Emmental region (canton of Berne, Switzerland). Intense rainfall, with totals reaching 96 mm locally, was largely restricted to the upper Emme catchment. Several steep tributaries of the Emme river produced massive debris floods and debris flows and transported large amounts of sediment and large wood (LW). The most active torrents (Sädelgraben and Gärtlebach) overtopped their channels and deposited ample amounts of material on the fans (Fig. 1). The local valley bottom road was obstructed by several meters of coarse material from the Sädelgraben.

The receiving Emme river produced an exceptionally large flood. At the runoff station Eggiwil (catchment area: 124 km^2), peak discharge reached 310 m^3 s^{-1} corresponding to a recurrence interval of far more than 200 years. The stream overflowed at various points along its reach and caused large-scale inundations and severe overbank sedimentation. Infrastructure, river protection structures as well as buildings were damaged and in some cases even destroyed. Moreover, widespread lateral bank erosion occurred all along the Emme entraining sediments and wood from alluvial forest stands.

A considerable amount of wood was recruited and deposited at the confluence of the lateral torrents with the Emme river and on the large inundated areas along the Emme. However, according to local eyewitness accounts, much wood was transported by the Emme river further downstream to clog a natural gorge (Räbloch, catchment size there: 96.4 km^2), where wood and other debris were piled up to a height of 8 to 10 m. At some point during the flood event this jammed structure failed and produced a flood wave rich in wood, some of which was transported all the way into the Aare river (some 50 km downstream).

After the flood event, the Swiss Federal Office for the Environment initiated a project to study the recruitment, transport and deposition of large wood in the upper catchment of the Emme. The goals of the investigation were to (i) establish a wood budget for the studied reach of the Emme river and its most active tributary, the Sädelgraben (1.3 km^2) including a survey of the deposited wood and the recruitment processes with an associated estimation of input volumes; (ii) investigate size distribution of mobilized and deposited wood pieces in the Sädelgraben and the Emme; (iii) identify and characterize wood recruited by bank erosion along the Emme river; and (iv) use pictures, videos and documentary information to complete the wood budget evaluation (because a significant amount of wood was removed immediately after the event).

Figure 1: Deposition of large woody jam on the left bank of the Sädelgrabe (tributary to the Emme river) after the debris flood of 24 July 2014.

Methods

Sädelgraben: In the aftermath of the flood event, wood deposits of the Sädelgraben were surveyed in detail. (1) The volumes of the wood piles that were stacked close to the main road by recovery operations immediately after the event, were determined by measuring the average length, width and height and by assuming a characteristic pore volume. To obtain a size distribution of the piled-up wood, a transect count for each pile was conducted. Pieces with a diameter and length larger than 10 and 50 cm, respectively, were considered. (2) More wood was deposited on the partially forested fan following massive overland flow caused by a channel failure. The deposition area was divided into several sectors with similar deposition density. For each sector one or several subareas were determined and all pieces of wood within were surveyed. With the resulting deposition density the wood volume for each sector was estimated by extrapolation.

For the determination of the wood input into the Sädelgraben, landslides as well as bank erosion along the torrent were mapped within the catchment, assuming that they had transferred wood into the channel. Contributing areas for both processes were estimated and associated reference areas defined and surveyed. To obtain a volume estimate of the entrained wood in the catchment, tree density and a typical tree diameter within the reference areas were determined and local conversion tables applied.

Emme: To determine the volume and size distribution of the deposited wood along the banks of the Emme river, a simplified method was applied. Classes for the diameter (5 cm increments up to 40 cm) and the length (2 m increments up to 16 m) of transported wood pieces were defined and combined to a grid. For all possible combinations of diameter and length, surveyed pieces were counted along the 10 km study perimeter upstream of the natural gorge (Räbloch). Bank erosion was measured and mapped, and the potential recruited wood volume will be estimated based on the riparian forest density.

Preliminary results

A preliminary wood budget of LW for the 24 July 2014 event in the Sädelgraben is proposed here. Deposited wood in the entire catchment (i.e. wood stacked up in piles, deposited on the fan, and deposited in the channel bed) amounts to approximately 450-550 m^3. The largest contribution is coming from fan deposits and is estimated to around 200 m^3. On the other hand, wood recruited by landslides and bank erosion as well as wood mobilized from the channel bed amounts to approximately 400-600 m^3. Here, the largest fraction of wood input appears to originate from landslides. The preliminary analysis also suggests that nearly 500 m^3 of wood was transported during the flood event and that only a negligible part of mobilized wood was exported from the catchment into the Emme river.

The size distribution of wood pieces transported in the Sädelgraben is different depending on whether wood pieces were stacked up in piles in the vicinity of the confluence with the Emme (originating from deposits along the downstream banks of the channel and from the area close to the clogged bridge of the valley bottom road) or naturally deposited on the fan (Fig. 2).

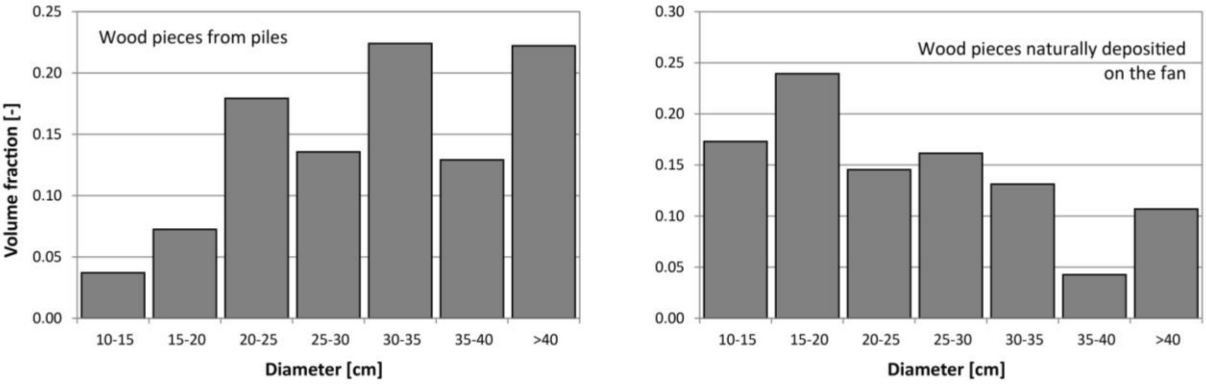

Figure 2: Size distribution of wood pieces surveyed along the Sädelgraben torrent: piled-up wood near the confluence with the Emme river (left) and naturally deposited wood on the fan (right).

Outlook and conclusions

A preliminary wood budget for a very active torrent catchment during the 24 July 2014 flood event in the upper Emme catchment was established. First results suggest that the large amount of large wood observed in the receiving Emme mountain river probably originated from bank erosion in the main river channel itself due to the extraordinary volume and erosive force of flood waters. Recruitment of LW from torrent tributaries seems to play a subordinate role in the budget of the Emme. Results from the field surveys (some of which will be finished only in early 2015) will be verified with available photographical material. Furthermore, wood recruitment and deposition areas will be localized on maps to illustrate the reconstructed wood budget.

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The impact of riparian vegetation on bank retreat evolution: A comparison between different fluvial systems, the Piave (Italy) and the King (Australia) rivers

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Abstract

Riparian vegetation plays a fundamental role in bank migration dynamics, enhancing soil cohesion through roots reinforcement. Despite of its well-known stabilizing effect, the active interaction between bank wooded vegetation and riverbank profiles in the evolution of bank retreat has been poorly studied. The present work proposes an analysis and comparison of bank tree and scallop (tree gaps in erosion along riverbank profiles) characteristics in two different fluvial environments, the Piave (Italy) and the King (Australia) rivers. The final aim is to uncover meaningful relationships explaining the control exerted by riparian trees on the planimetric migration of riverbanks. Significant results have reported common as well as dissimilar responses between the two rivers, the latter possibly due to their very different physical and hydraulic characteristics. Tree spacing has showed a common influence on the evolution of scalloped bank profiles, confirming the importance of riparian vegetation in reducing bank retreat.

Keywords: Riparian vegetation; Bank retreat; Scallops; Channel evolution.

Introduction

Vegetation represents a key element in fluvial systems, controlling and being controlled at the same time by river processes. Alive or dead, wooded vegetation may affect a large array of stream dynamics, including hydraulics, sediment transfer and ecology (Piégay, 2003). Along riverbanks, trees and shrubs actively interact with sediment and water flow, producing stabilizing as well as destabilizing effects. One of the most important and recognized influence of riparian vegetation on riverbanks is the capability of generating soil cohesion through the root plates (Abernethy and Rutherfurd, 2001). Roots reinforce soil structure decreasing tension-crack formation, thus reducing both the shear stress and the likelihood of mass failure (Hubble et al., 2010). When channels migrate past riparian trees, slower local erosion due to roots resistance may create a scalloped bank-line, with protruding tree abutments and root crowns representing evidences of the erosion-resistant effect of woody vegetation (Rutherfurd and Grove, 2004). Even though research has demonstrated the effective contribution of riparian vegetation in slowing down bank erosion and migration (Allmendinger et al., 2005), several aspects related to such theory remain unknown. Among these, the characteristics of tree spaces (in particular erosive, scallops) along riverbank profiles have been poorly investigated and scarcely integrated in the evolution of bank migration processes. Additionally, empirical models developed so far to describe bank retreat development in forested riverbanks (Pizzuto et al., 2010) have demonstrated inadequate to comprehensively explain this phenomenon. A better understanding of how bank planimetric profiles evolve across riverbanks characterized by different vegetation structures and sediment properties would help river experts to deal properly with riparian vegetation in fluvial systems.

This study aims at analysing and comparing bank retreat processes along forested riverbanks of two fluvial systems, the Piave (Italy) and King (Australia) rivers, characterized by many physical and functioning differences, including sediment composition. Similar and dissimilar trends are carefully examined to understand the control exerted by bank trees on the planimetric evolution of migrating riverbanks. The results offer the opportunity of identifying characteristics of riparian vegetation that are relevant to reduce bank retreat.

Study Area

The first study area is represented by the Piave River, a gravel-bed river located in north-eastern Italy, flowing from the Alps until the Adriatic Sea. Its total length is about 220 km, whereas its total drainage basin accounts for 3,900 km^2 approximately (Comiti et al., 2011). The study reach, called Belluno, is located in the piedmont area and features morphological patterns dominated by braided and wandering dynamics (drainage basin of 1,690 km^2) . The length of the entire study reach is 2.2 km with a maximum active channel width reaching almost 500 m. Four arched bank profiles characterized by lateral migration processes were selected for the study (Fig. 1a).

The second study area is the King River, a tributary of the Ovens River, located in north-eastern Victoria, Australia. Featuring a length of 126 km and a drainage area of 1,400 km^2, the King River is characterized by avulsion processes, especially in the second half of its course when valley and channel slope markedly decrease (Schumm et al., 1996). The study reach embodies a low-gradient sinuous portion of the stream, 15-20 m wide and 2-3 m deep with a clay-sandy sediment composition. Bank profiles are characterized by different tree densities and sizes and feature extensive root-plate abutments and scalloping phenomena (Fig. 1b). In the study reach, ten sub-reaches were selected taking into account the representativeness of the different avulsion stages and morphological sections.

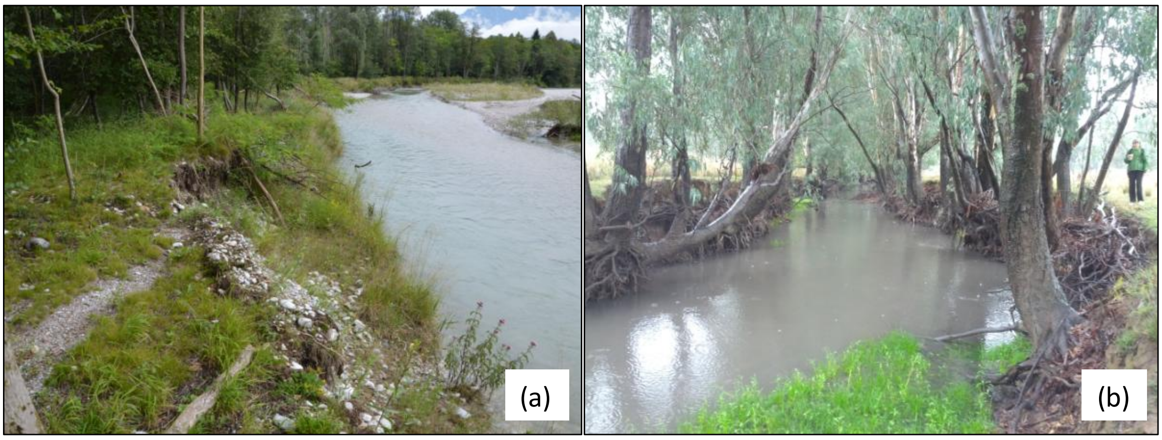

Fig. 1: Scalloped bank profiles on the Piave (a) and King (b) rivers.

Materials and Methods

Measurements of trees and tree gaps on both rivers were performed through devices widely used in fluvial geomorphology as measuring stadia and tape, compass and tree caliper. On the Piave River, a total of 101 trees and 97 tree spaces were surveyed along four arched bank profiles featuring lateral migration processes. Only 34 tree gaps were erosional, so called scallops, and thus considered in this study. On the King River, 538 trees and 518 tree gaps were totally acquired along twenty longitudinal bank profiles with different morphological characteristics. Here, only 104 tree gaps were erosional, so called scallops, and thus considered in this study. For each tree, information of species, diameter at breast height, position and canopy radius, were acquired. Additionally, bank tree location was surveyed with a dGPS for further digitalization purposes in ArcGIS environment. Tree spaces along bank profiles were then analyzed through the following measurements: total spacing considering as outer limits the bank profile points in-line with the two boundary trees, form, presence and position along the spacing of any apex greater than 0.5 m in depth and apex depth.

Results

Tree and scallop interactions analyzed in the Piave and King rivers have reported common as well as different trends describing bank retreat evolution through forested riverbanks. Differences were found in the vegetation structure of bank profiles with the Piave River featuring a much higher species variability than the King River. Another important discrepancy regards the position of trees on banks. If in the King River trees feature on top or face of banks with root plates generally exposed at some degree, in the Piave River they are located on the bank-top, or more frequently, at an inner distance from the bank crest and little or no root exposure is present.

Common responses were found in the average magnitude of scallop depth that resulted to be equal and comparable in the two river systems (median of 0.95 m), even with a greater variance on the King River. Further, the search for relationships linking scallop depth to bank tree characteristics has underscored the irrelevant role of tree size in affecting the development of scalloped bank profiles. By contrast, tree spacing has demonstrated to explain at some degree the evolution of scallops. Specifically, the distance of riparian trees appears to influence more scallop depth on the Piave River (R^2 = 0.69) than on the King River (R^2 = 0.42). Furthermore, the outer bends of the King River and the arched bank profiles found on the Piave River were considered as individual elements and compared, plotting their average tree spacing to explain the average scallop depth (Fig. 2). Despite the lower number of observations on the Piave River, the two fluvial systems confirm to have fairly comparable magnitudes of scallop processes. King River's bends show a similar degree of influence produced by tree spacing (R^2 = 0.45) to that resulted by considering all scallops together. By contrast, Piave River's arcs report a significantly higher relationship explaining scallop depth (R^2 = 0.82) than that featured without this morphological subdivision.

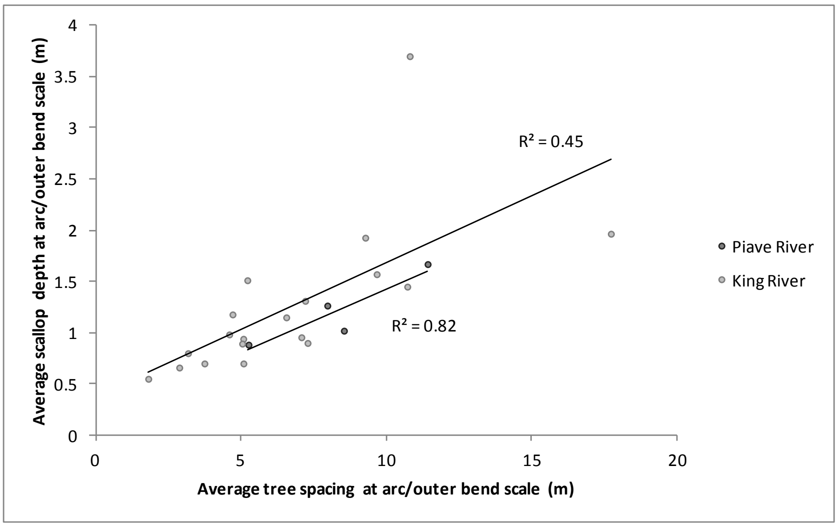

Fig. 2: Impact of average tree spacing on average scallop depth at arc/bend scale (Piave and King rivers).

Discussions and Conclusions

The compared vegetation and bank-profile characteristics have shown common and dissimilar trends describing the control exerted by riparian trees on bank retreat processes on the Piave and the King rivers. The different number of observations carried out on the two rivers is a crucial aspect to account in the explanation of our results. A fundamental difference was found in the position of trees along riverbanks that resulted totally on the bank-top in the Piave River and mostly on the bank-face in the King River. This characteristic may lead to strong impacts on bank retreat development, modifying hydraulic processes and, in turn, the removal mechanisms affecting bank vegetation and sediment. Similar patterns were found in the average magnitude of scallop depth, possibly describing a little role played by bank sediment properties. The higher influence of tree spacing on scallop depth observed in the Piave River might be due to the less structural stability of non-cohesive sediment that with a low degree of adherence can be easily scoured away or fall down the bank face. Finally, the comparison of the average impact of tree spacing at bend- (King River) and arc- (Piave River) scale has showed the importance of considering appropriate morphological units in the investigation of bank retreat dynamics. Reaching almost the double degree of correlation than in the King River's case, scallop processes on the Piave River seem to need to be handled at arc-scale to provide more meaningful results.

Different behaviors encountered on the Piave and King rivers in relation to the control exerted by bank trees on bank retreat processes could possibly be explained also by their different functioning dynamics. The larger spatial extent, topographic gradient, flow regime of the Piave River along with its non-cohesive sediment composition, may strongly influence the morphological dynamics of this system. Floods also below the bankfull may cause a significant channel reconfiguration, where the control of bank trees in reducing bank retreat can be outclassed by the force of fluvial scour, eroding large portions of riverbanks. Nevertheless, bank tree spacing have overall confirmed to be an important element, able to reduce bank retreat processes in different environments and thus offering new insights for river management purposes.

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Large wood mobility in a mountain basin of North-eastern Italy

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Abstract

Mobility and transport distance of LW elements of different size and shape is being monitored through repeated surveys of tagged logs in different reaches of the main Rienz River (630 km^2, Eastern Italian Alps) and in one of its tributaries, the Brunst Creek (11.3 km^2). 154 Naturally recruited and artificially introduced logs with average lengths of 6.6 m in the Rienz and 2.5 m in the Brunst, have been tracked after near bankfull events along 5 km length reach in the Rienz and 1 km in the Brunst for 3 years, registering 172 displacements.

The results show that both, mobility and displacement length, seem to be highly influence by channel morphology characteristics rather than by hydraulic variables. This kind of studies is relevant to understand the large wood dynamics and validate or develop new LW transport models.

Keywords: *Large wood transport, Large wood tracking, Channel morphology.*

Introduction

Large wood (LW) represents one of the main problems for risk prediction in forested mountain streams, mostly because of its potential to clog bridges and narrow sections during flood events. However, LW dynamics are poorly understood and long term studies are very scarce (Wohl and Goode, 2008).

However, in the last decade, new methods are being used to monitor LW displacements and study their dynamics such as LW tracking, time lapse photography or videos (MacVicar et al., 2009; Kramer and Wohl, 2014). The data obtained with these kinds of techniques are essential to validate and develop LW transport models (Mazzorana et al., 2011; Ruiz-Villanueva et al., 2014; Lucía et al., 2015).

We have tracked tagged logs, documenting their mobility and measuring the transport distance in the Rienz catchment, where it has been evidenced the role of the LW increasing the flood hazard during past events. In order to prevent this risk, two wood trapping structures upstream the town of Brunek in the main Rienz channel have been recently built (Comiti et al., 2012).

Study Area

The study area is the Rienz/Rienza River basin and one of its tributary, the Brunst Creek, located in the eastern Italian Alps, upstream of the city of Bruneck/Brunico (Fig. 1). The drainage area of the Rienz at Bruneck is 630 km^2, whereas the Brunst basin is 11 km^2. A large proportion of the basin (57%) is covered by forest (mostly composed by *Picea abies* and *Larix decidua*). The Rienz basin features minimum and maximum elevation of 811 m and 3430 m, respectively, while the Brunst min elevation is 995 m and maximum 2564 m.

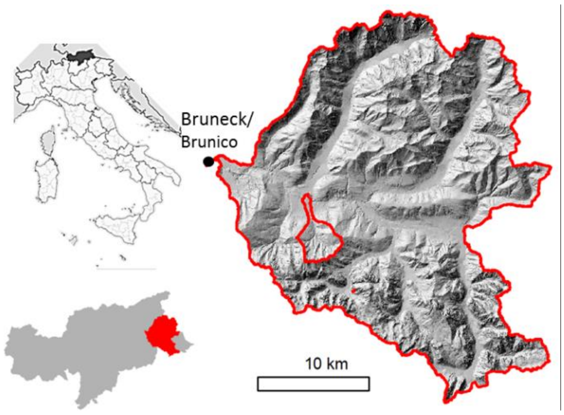

Figure 1: Location of Rienz catchment upstream of Bruneck/Brunico, and the Brunst Creek.

Methods

The position of logs (154 in total) identified with metal tags is being monitored since 2010 by DGPS in the Rienz and in the Brunst channel (Fig. 2). The dimensions of the logs were measured and their shape, described.

In the Rienz, the average length of the 50 cylindrical artificially introduced logs is 6 m (2-10.5 m) and 0.31 m of diameter (0.11-0.58 m). The artificially introduced trees with rootwad and canopy are 17, with an average length of 11 m (4.2-20 m) and diameter of 0.18 (0.11-0.27 m). The naturally recruited tagged logs are 43 and they measure 4.98 m length (0.5-26.4 m) and 0.19 m of diameter (0.08-0.52 m)

In the Brunst, all the artificially introduced logs are 1 m long and their diameters are 0.1 m (varying from 0.06 to 0.14); 10 of them have branches and 10 of them are cylindrical. The naturally recruited tagged logs are 23 and they measure 3.86 m long (0.7-16.0 m) and 0.15 m of diameter (0.07-0.28).

In the reaches where the LW transport has been monitored, 19 cross sections were surveyed in the Rienz and 4 in the Brunst. In the Rienz, average bankfull channel width is 12.6 m and slope 1.4%. In the Brunst, average bankfull width is 3.5 m and slope 17.2%. The logs that have been tracked have similar dimensions to the bankfull channel width.

To analyze the incipient motion conditions and travel distance of these logs, flow stage is monitored after each potentially relevant flow event at the cross-sections. Log location, orientation, position in the channel and the anchoring degree are assessed after each event.

Figure 2: Log placement in a reach of the Rienz River.

Results

During the monitored events, all of them close or below to the bankfull discharge, 172 log displacements have been registered with an average transport distance of 0.5 km in the Rienz River. However, variability in travel distance is very high, with a maximum value of 3 km. Results indicate that mobility and transport at moderate to bankfull events are poorly related to hydraulic variables (water depth) (Fig. 3), and reach morphology, boulder spatial density, anchoring degree and log characteristics (presence/absence of roots and branches) are more relevant.

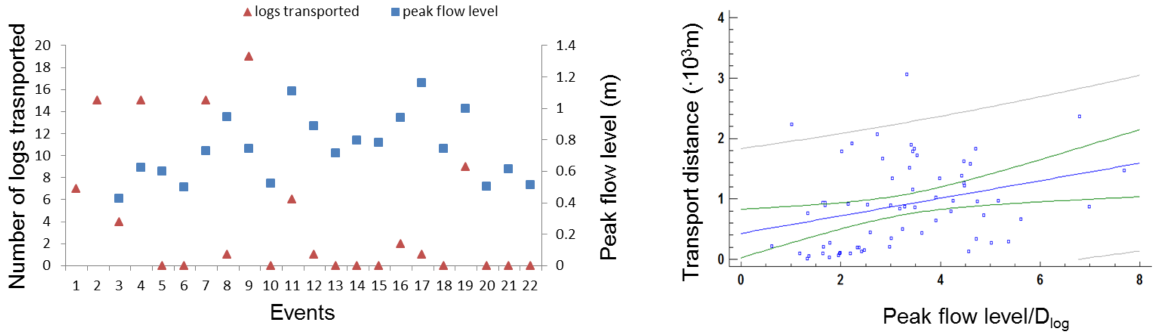

Figure 3: Left: Log transported in the different events of the 2012 (1 to 17) and 2013 (18 to 22). The number of displacements is not related with the peak flow level and it is reduced with the time. Right: Hydraulic parameters do not explain the variability in transport distance

Discussions and Conclusions

LW transport in the investigated mountain rivers during moderate to bankfull events resulted to be mostly controlled by channel morphology, primarily channel width and roughness.

Further analysis on logistic regressions including all the investigated variables are expected to shed some light to the LW transport dynamics in mountain catchments.

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Large Wood recruitment from floodplains and fluvial island

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Abstract

During the last years there was an increasing attention on Large Wood (LW), due to its role in influencing riverine processes and to its impact along fluvial systems. Particularly attention were devoted to the characterization of LW, while there is still a lack of knowledge about its recruitment. This study aims to analyze the recruitment of LW along a reach of a gravel bed river after an over-bankfull flood. The analysis were carried out along a reach of the middle course of the Piave River (North-East Italy). A buffer zone of 20 m–wide was established along floodplains and islands. Into this area all the standing trees with diameter ≥ 0.10 m were manually measured (Diameter Breast Height–DBH; Height), numbered tags were installed on each tree considered and its position were collected using a differential GPS. After an over-bankfull flood occurred in November 2014 (Q = 1329 m^3s^{-1}; R.I = 6 years), field survey were carried out. During the flood event 428 and 247 were recruited from the floodplains and islands, respectively. A total amount of 80.92 m^3 (0.19 m^3/tree) and 39.88 m^3 (0.16 m^3/tree) was inserted into the active channel from floodplains and islands, respectively. Field survey permitted to recover 155 and 32 trees coming from floodplains and island, respectively. For each tree, the displacement length was calculated, with maximum values of about 3642 m and 1024 m for trees coming from floodplains and islands, respectively. These results give useful indication for the management of the riparian vegetation.

Key words: Large Wood; Large Wood recruitment; Gravel bed river; floodplain; fluvial island; Piave River.

Introduction

Large Wood (LW) in riverine environments exerts many different important functions on hydrology, morphology and ecology aspects (Piégay, 2003; Seo *et al.*, 2010; Gurnell, 2013). On the other hand, it is necessary to underline that LW represent a potential hazard during flood events particularly interacting with sensitive structures as bridges (Mazzorana et al., 2011). Consequently more attention has devoted to LW, during the most recent years an increasing attention has been dedicated to define the wood budget (Schenk et al., 2013). Typically, the wood budget is defined as the sum of inputs (transport from upstream, recruitment from banks) and outputs (downstream transport, overbank deposition and decay) (Martin and Benda, 2001). However, there is still a lack of information about the lateral recruitment of LW from floodplains and fluvial islands in large gravel bed rivers environments. This study aims to better characterize the differences in recruitment from these two geomorphic units and increase the knowledge of LW transport after its recruitment, as to give more detail and information useful for a better management of the riparian area.

Study area

The Piave River flows south from the Alps (≈ 2000 m a.s.l.) for 220 km to the mouth in the Adriatic Sea, close to Venice. Its basin present a drainage area of about 3899 km^2. The Piave River is a gravel bed river historically affected by human activities (hydropower schemes, bank protections and gravel mining activities), over the basin and along the main channel (Comiti et al., 2011).The study has been carried out along a 3 km – long study reach located into the middle course of the Piave River. The reach has a width of about 400 m, mean slope of about 0.4 % and a transitional morphology between braided and wandering, and it is characterized by the presence of a big established island in the middle part of the reach.

Methods

A buffer zone of 20 m–wide was considered along the floodplains and islands. Into this stripe manual measurements were taken for every standing tree with diameter ≥ 0.10 m (Diameter Breast Height–DBH; Height). Moreover, for each tree the GPS position was recorded and a numbered tag was installed to simplify the post event recovery. The volume of each tree was calculated following Boivin et al. (2015)**.** In November 2014 an over-bankfull flood (Q = 1329 m^3s^{-1}; R.I = 6 years) occurred. After this flood, field surveys were carried out. Moving downstream from the upper part of the study area, every single LW has been checked to recognize tagged plants. For each tagged LW, GPS position and some qualitative details (morphological unit, orientation respect to the main flow direction, single or accumulation) (Ravazzolo et al., 2015) were registered.

Results

The over-bankfull flood eroded considerable portion of both islands and floodplain. The three erosional processes occurred along the floodplain appear similar, in fact these show extension of about 5514 m^2, 4925 m^2 and 4802 m^2, respectively. On the other hand there is a considerable difference between the size of the two erosional processes detected along the bigger fluvial island of the study reach (≈ 931 m^2 and 12860 m^2, respectively). From the floodplain there was input of about 428 trees for a total volume of about 80.92 m^3 (0.19 m^3/tree), while from the islands there was recruitment of about 247 trees corresponding to a LW volume of about 39.88 m^3 (0.16 m^3/tree). The trees recruited from the floodplain are characterized by maximum and mean height of about 20.00 m and 8.88 m, respectively; while the maximum and mean diameter are 0.54 m and 0.14 m, respectively. On the other hand, the trees recruited by the island are characterized by maximum and mean height of about 15.00 m and 6.64 m, respectively. The maximum diameter is 0.44 m, while the mean one is 0.14 m.

During the post event field survey has been possible to find 155 trees recruited from floodplain (recovery rate = 36.21 %) and 32 trees coming from islands (recovery rate = 12.96 %). Thanks to these results has been possible detect also the travel distance for these recruited trees. Looking at the floodplain input, the minimum and maximum displacement distance ranges from 1 m to 3642 m, respectively. On the other hand, the recruited trees from islands were transported for a minimum and maximum distance of around 3 m and 1024, respectively. Considering the displacement length and the recruited tree diameter (Fig. 1) it is possible to underline as the highest travel distance correspond to the lower diameter, but it is not possible to define a clear correlation between these data. On the other hand, connecting the travel distance to the height (Fig.1) it is possible to note as the highest displacement do not correspond to the smaller tree (1 m height) but to a tree of 6 m tall.

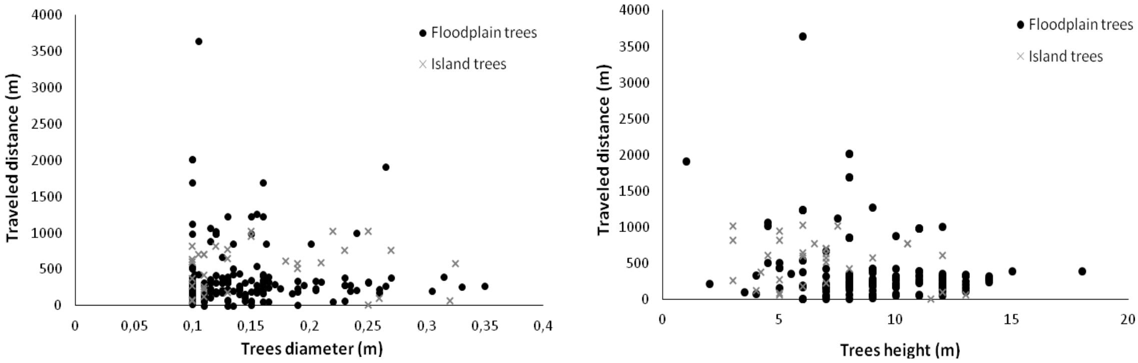

Figure 1: correlation between travel distance and recruited tree diameter (on the left), and between travel distance and recruited tree height (on the right)

Discussion and conclusion

These preliminary results suggest as the recruitment of LW due to bank erosion can be a considerable source of LW also during not extraordinary floods. A total amount of around 120 m^3, can be considered as considerable also because of the short length of the analysed reach. Interesting are the results relating to the subsequent transport of the LW after its recruitment. Though the Piave River is heavily impacted by hydropower schemes and water diversions, a not extraordinary flood can produce important displacement of logs. In this case the results suggest as the travel distance are higher than what already presented (Ravazzolo et al., this conference) though during higher flood events. These results can help planning the management of the riparian vegetation, particularly in the area prone to erosion and located just upstream of sensitive structures or river sections. Future challenges will be to better investigate the displacement trajectories after the recruitment and the mechanisms of resistance of the different vegetation cover types.

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Impact of instream wood on bank erosion

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Abstract

There has been abundant research into the effect of tree roots on stabilizing river banks, and also on the effect of trees on bed-scour after they have fallen into the stream, but there is little research into the effect of fallen trees on bank erosion. Here we develop the hydraulic theory that predicts erosion associated with trees and conclude that individual trees can increase local bank erosion, but multiple trees can reduce overall reach erosion. For consistent bank resistance, the local erosion varies in a non-linear way with the position and angle of the log, and its blockage ratio. The reach scale effect of the wood depends on the load and distribution of logs through the reach. Erosion effects of instream wood are difficult to measure. We are testing the above theory and model of erosion around wood in an ideal setting below a large irrigation dam on the Murray River in SE Australia. The consistent regulated flow, combined with multiple anabranching channels of different sizes, and abundant fallen trees, provides an environment in which we can measure erosion as well as hydraulics in a controlled condition.

Keywords: *Bank erosion; Shear stress; Velocity field; Blockage ratio.*

Problem

Large instream wood alters the hydrological, geomorphological, and ecological structure of rivers, as it induces diversity of flow hydraulics and channel form, and creates habitats for aquatic fauna (Keller & Swanson, 1979; Abbe & Montgomery, 2003). There is substantial literature on the influence of live riparian trees on bank stability (Abernethy & Rutherfurd, 1998; Rowntree & Dollar, 1999), and on bed complexity due to scour around fallen trees (Abbe & Montgomery, 1996), but there is little research into the bank erosion adjacent to fallen trees. Concern about erosion around fallen trees is one of the major reasons why river managers continue to remove wood from low-land streams in Australia. In this paper we describe the theory of erosion around logs of different size and configuration, as well as the combined effect of multiple logs in a reach. We then briefly describe our approach to testing the theory in the field

Theory of bank erosion around logs

Wood in rivers functions as a roughness element, producing friction to decelerate the flow (Gippel, 1995); however the wood also deflects the flow to create acceleration zones (i.e. a hydraulic jet) between the wood and the channel bank (Daniels & Rhoads, 2003). High shear stress in the acceleration zone can exceed the critical shear stress of the bank (Die Moran et al, 2013) until the shear stress falls below the critical shear stress of the bank.

Single Logs

For given bank resistance, the change of bank shear stress adjacent to the wood can be estimated by the wood characteristics including the blockage ratio (ratio of the projected area of the log to the channel xsec area), orientation and location of the log (Fig. 1).

For the same log angle, the shear stress between the log and the bank increases with blockage ratio, and decreases with the distance from the bank. The shear as the log angle decreases from 90^{o} (perpendicular to flow) toward 30^{o}, the shear stress decreases non-linearly, and beyond 30^{o} the hydraulic jet is constricted, increasing the length of the scour zone along the bank (Fig. 2).

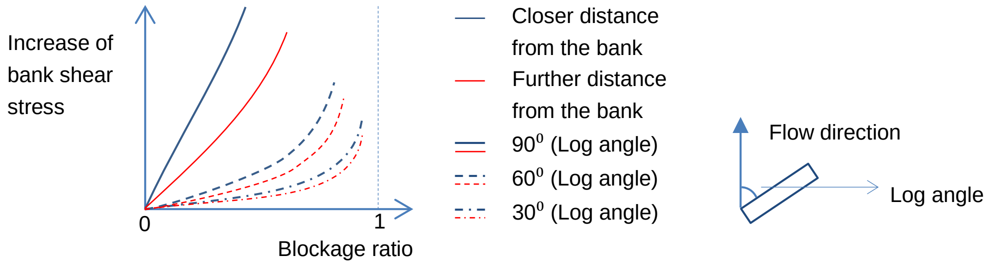

Figure 1: relationship between increase of bank shear stress and wood characteristics

Erosion around a single log also varies with discharge (Fig. 3). The increase of the bank shear stress peaks after the log is fully submerged and decreases as the log is drowned-out. Discharge keeps increasing as the flow regime dominates the erosion process in this stage. As the log number increases in a giving reach, the average effect of a log decreases and the peak effect appears with lower discharge.

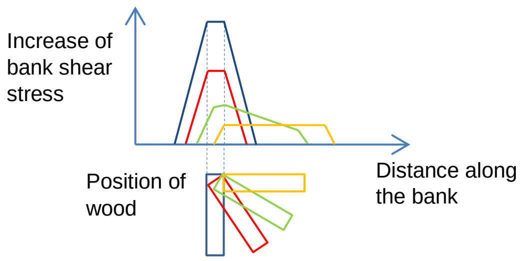

Figure 2: Predicted extent of bank shear stress increase along the bank

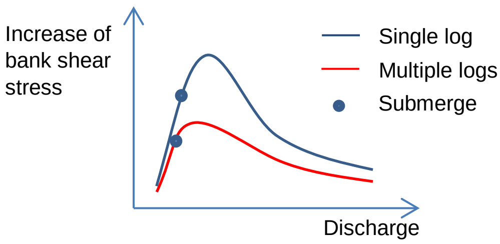

Figure 3: Predicted influence of discharge on bank stress increase

Incorporating the contraction and friction functions of wood in altering bank shear stress, a model is developed to predict the change of bank shear stress adjacent to the wood (Eqn. 1). In the contraction process the flow is accelerated and the wood produces an increase of bank shear stress which can be derived from the energy conservation and mass continuity equation (Eqn. 2). An energy loss equation of shape change in pipes based on the Bernoulli Equation is adopted to describe the energy loss from the flow contraction. In the friction process the flow is decelerated and the wood produces a decrease of bank shear stress which can be derived from the drag force equation of the wood (Eqn. 3).

$$\Delta\tau = \tau_c - \tau_f \tag{1}$$

$$\tau_c = \frac{1}{2}\rho\frac{1}{d}\left(1 - B_p\right)^{-2} B_p v_{app}^2 y \tag{2}$$

$$\tau_f = \frac{1}{2}\rho C_D'(1 - B)^{-2} B v_{app}^2 y \tag{3}$$

where $\Delta\tau =$ increase of bank shear stress adjacent to the wood; $\tau_c, \tau_f =$ contraction and friction shear stress component associated with wood, respectively; $d =$ wood diameter; $B =$ total blockage ratio which is the ratio of wood frontal area and cross-section area; $B_p =$ particle blockage ratio which represents the contraction rate of the deflected flow; $C_D' =$ wood drag coefficient; $v_{app} =$ mean approach flow velocity; $y =$ flow depth.

Multiple Logs

The friction component in Eqn. 3 produces a backwater upstream of the log. If there is another log inside that backwater extent, then the amount of erosion will be reduced. At some log frequency, the multiple logs will reduce velocities and shear stress throughout the reach, eventually reducing the net erosion rate (Fig. 4). However, this effect depends strongly on the arrangement of logs (particularly jams).

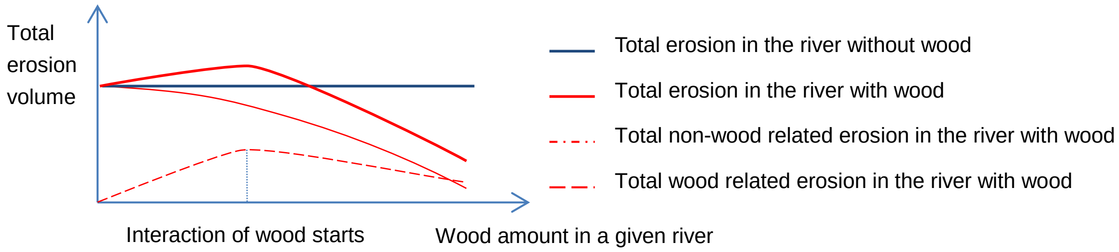

Figure 4: Relationship between total erosion volume and wood amount in a river

Field Test

It is difficult to validate the theory proposed above because there are so many variations in the logs, the flow and the channel characteristics. It could be done in a flume, but it is notoriously hard to measure bank erosion in a flume. Instead we are testing the theory in a field setting where we can control as many of the variables as possible. A reach of the Murray River in SE Australia is heavily regulated for irrigation flows from a large dam (Hume Weir), and the channel below the dam consists of multiple anabranching channels with (a) a huge range of channel sizes that experience very consistent seasonal flows; (b) high erosion rates that deliver large numbers of large trees to the river channel (river red gums, *Eucalyptus camaldulensis*). As a result we can, over successive irrigation seasons, measure erosion (using repeat photogrammetry), as well as hydraulics (using an acoustic Doppler velocity profiler), in order to test the theory in a controlled environment. The erosion and hydraulics are being related to wood characteristics including length, diameter, orientation, and distance from the bank. The erodibility of the bank material will be tested in site by hydraulic jet apparatus to estimate the erosion volume with the prediction model.

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Large wood transport during the 2005 flood events in Switzerland

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Keywords: *large wood; mountain stream; sediment transport; wood transport*

Introduction

Severe floods occurred on 20-23 August 2005 in Switzerland, covering a large part of the Nothern Alps and lasting for several days. These floods were associated with enormous morphologic changes along the stream channels and with large sediment transport (Rickenmann & Koschni, 2010). The typical features of the event included (i) high activity of small scale landslide and debris flow in steep mountain catchments, (ii) extreme discharges with river bank erosion and sediment transport in many meso-scale river catchments, (iii) LW triggered flooding in the larger mountain rivers in the Swiss Plateau (Bezzola & Hegg, 2008). Apart from flooding, erosion and aggradation of sediments, considerable amounts of large wood (LW) were transported. The combination of all these processes resulted in high damage costs (Badoux et al., 2014).

Study area and methods

The aim of this study was to document the process of LW transport which occurred during the 2005 flood events (Waldner et al., 2008). This included the identification of source areas and entrainment process and the main areas and volumes of deposition. Source areas of LW entrainment as well as deposit volumes were determined within an integral hazard process documentation using a harmonized protocol (StorMe, 2006) by professionals in the weeks after the event. In addition, the dimensions and characteristics of deposited LW pieces were determined with line transects for selected large LW accumulations. The main study areas are shown in Figure 1. For some catchments, a budget over LW entrainment and deposition was established. Additional information was gained from comparison of pairs of LiDAR and air photograph surveys obtained before and after the flood events.

Figure 1: Main study areas of LW transport which occurred during the August 2005 flood events in Northern Switzerland.

Selected results

In this study a fairly comprehensive inventory of LW recruitment and entrainment processes in mountain stream catchments was elaborated. In particular, wood transport rates and budgets were determined for four study meso-scale catchments, with catchment areas ranging from about 20 to 600 km^2; the estimates of entrained and deposited large wood volumes in these catchments varied from 4000 to 31,000 m^3. The main entrainment processes for LW were identified as debris flows, landslides, and river bank erosion of fresh wood as well as re-floating of LW in the bed deposited earlier. Only a minor contribution resulted from construction wood. Figure 2 illustrates the main entrainment processes and volumes of LW in the source areas and the depositional locations for the example of the Kander and Simme catchment.

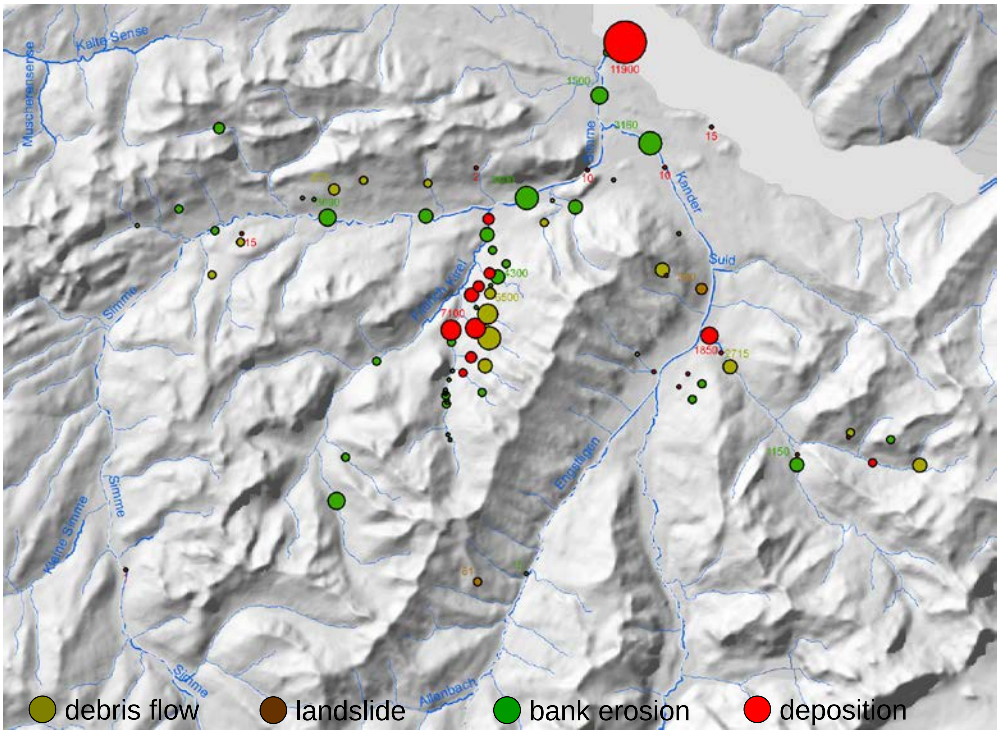

Figure 2: Main entrainment processes, source and deposition areas, and volumes of LW (in m^3) observed for the 20-23 August 2005 flood event in the Kander and Simme catchment. (background image: Swiss Federal Office for Statistics, and reproduced by permission of swisstopo JA100118).

Considering the dimensions of the deposited large wood pieces, the measured lengths varied between about 1 and 12 m, with only a small percentage having lengths larger than 12 m. However, only a minor part of the examined wood was completely untouched until assessment. The observed diameters varied from a about 5 to 70 cm, with a peak in the range of 15 to 50 cm. For this peak range of diameters, the estimated original mean lengths of the entrained trees vary from about 17 to 27 m (Stetter, 2014). This implies that the tree logs were considerably reduced in length due to mechanical forces acting during the LW transport process and during the immediate emergency and recovery work carried out by local hazard protection services prior to the assessment of the LW deposits.

The transported LW was deposited at several types of locations: a remarkable part of the mobilized LW was deposited in shallow water at locations of stream channel enlargement. LW passed over natural beds and along river engineering constructions causing little damage over large distances. However, it also clogged in log jams at bridges and weirs with smaller freeboard or outlet spacing. Triggering overtopping processes, such clogging considerably increased the flood damage. Large amounts accumulated around river mouths at piedmont lakes, where it was partly stopped from spreading and moving further by floating barriers.

Conclusions

Comprehensive budgets of LW transported during storm runoff in torrents and mountain rivers were established for the large flood events of August 2005 in Switzerland. The main entrainment and deposition processes were identified and quantified. Rare hazard events with extensive damage of remote forests contributed to a remarkable part of the transported LW. Clogging of LW at bridges and weirs with smaller outlet dimensions considerably increased the total flood damage.

Acknowledgements

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Significance of woody debris in the dynamic of bedload transport (Polish flysch Carpathians)

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Keywords: Large Woody Debris, bedload, abrasion, Polish flysch Carpathians

Introduction

Wood in stream channels are important components of forest ecosystem. Many authors emphasized the role of woody debris in capturing of a transported mineral material (Zimmermann & Church, 2001; Diez et al., 2001; Montgomery et al., 2003). In longitudinal profile of river channels, steps which are made of woody debris amount from 12 to 58 percent. Moreover, woody debris are stabile during a long period which is determined only by the time of wood decomposition (Keller & Swanson, 1979; Mosley, 1981). Steps made of woody debris are more effective in capturing of mineral material than bedrock steps (Thompson 1995). Occurrence of Large Woody Debris (LWD) within streams, by crating step-pool morphology, affect channel hydraulic conditions. LWD increase channel roughness and hence reduce flow velocity and dissipate kinetic energy of flowing water. Therefore, LWD influence a distribution of erosion and deposition reaches, armor the channels and form local base-levels (Marston, 1982; Adenlof & Wohl, 1994; Curran & Wohl, 2003). The most important parameter of LWD is length in relation to channel width. Such characteristic of LWD is important when we consider woody debris transport as well as ability for trapping of mineral material (Swanson et al., 1998).
The main issue of the research was to recognize the role of LWD within stream channel in different scales: from reaches through steps and pools to single coarser particles. Subsequently, detailed characteristic of woody debris and mechanical properties (self-abrasion) of bedload material was performed.

Study Area

Dupniański Stream is situated in a mountain forest catchment belonging to the basin of the Upper Olza River. Stream is a right tributary of the Olza River. The catchment area covers 1.68 km^2, and the length of the main stream is 2,09 km. The maximum elevation within the catchment area reaches 881.90 meters above sea level, the minimum is 492.70 m above sea level (main watercourse mounth height). A characteristic feature of the catchment is the opening of the valley on the south side of the valley at the course in the N–S. Stream gradient is 16%. Orographic conditions set for Dupniański Stream are characteristic for most part of the Silesian Beskid. Watercourse headwaters height is 808.75m a.s.l. and total length of watercourse is 5.7km. Water network density: 3,43 km.km^{-2}.
Catchment of the Dupniański Stream has a high rate of forest cover, with a negligible share of agricultural land and non-forest area. Description of the catchment against the hydrological conditions of Silesian Beskid to suggest that, despite the formal membership Dupniański Stream to the Olza River catchment, it represents the full terms and conditions of streams belonging to the Carpathian Basin. According to the distribution of the hydrogeological study area catchment of Dupniański Stream is located in the Carpathian region. Occuring in this area flysch sandstone - shale are less permeable and thus are of low retention capacity. Narrow ridges of

the corrugated lines are separated by valleys with a depth of 400 - 600 m, with numerous rapids and waterfalls and rocky slopes. Southern slopes are often modeled by a landslide. As an object of study four different reaches were selected.

Materials and Methods

The surveys included: 1) woody debris localization and characteristic in terms of diameter, shape, direction and mechanism of supply 2) sampling of the bedload as well as fine mineral material 3) measurement of a largest grain's diameter (three axis), 3) assessment of an arrangement (direction and inclination of the longest axis) and a roundness of the largest particles, 4) documentation (photography, schemes, profiles). Subsequently, on the basis of the measurements of all axis (Zinga method), the particles were classified and the flattening of each sample was established.

The measurements of woody debris and bedload was conducted parallel with the measurements of Dupniański stream channel parameters such as: unit stream power expressed as: $\omega = (\rho gQS)/w$ where ρ – water density, g – acceleration due to gravity, Q – discharge, S – slope of channel reach, w – channel width, measured in the field and as: $\omega = AS/w$; where A – contributing area, were derived from Lidar Digital Elevation Model (DEM) analysis. and Manning formula: $v_{av}=R^{2/3}S^{1/2}/n$ where R - hydraulic radius, S – bed slope, n – Manning roughness derived from the filed measurement. A fine grains were analyzed in terms of Folk, Word coefficients; Mean particle diameter (Mz), sorting (δ), skewness (Sk) were determined.

All measurement were performed in the purpose of the recognition of an influence of LWD on the direction of water flow and consequently on the distribution of mineral material.

Results

LWD influence channel morphology, hydraulic and bedload transport of Dupniański Stream. Depending on reach characteristic distribution, stability and physical characteristic of woody debris bedload is diversified. In the reach number one, in comparison with others, the smallest amount of woody debris was observed. Shape, diameter and direction of woody debris indicate ability of the reach to maintain wood debris transport only during high energy hydrological events. Nevertheless, due to the occurrence of bedrock steps only few logjams were observed. In the second, third and fourth of analyzed reaches, woody debris form step-pool morphology with steps (about 0.5 m high) distributed 1 to 4.5 m from each other's. Woody debris steps are built of wood transported from the reaches located above the ones with single artificially deposited trunks (forest reconstruction). In all analyzed reaches mineral material was deposited mainly above and below woody debris steps. Coarser particles were found above all steps (Fig. 2) while fine mineral material was deposited within pools.

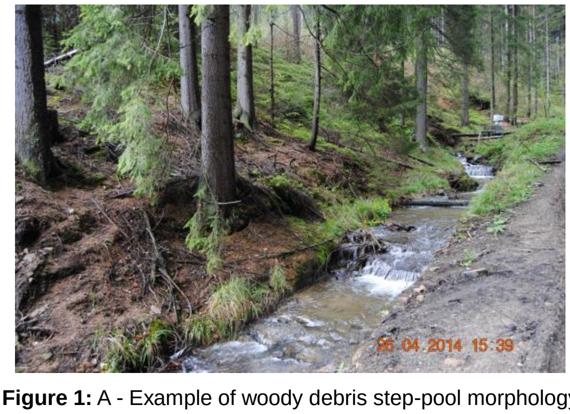

Figure 1: A - Example of woody debris step-pool morphology

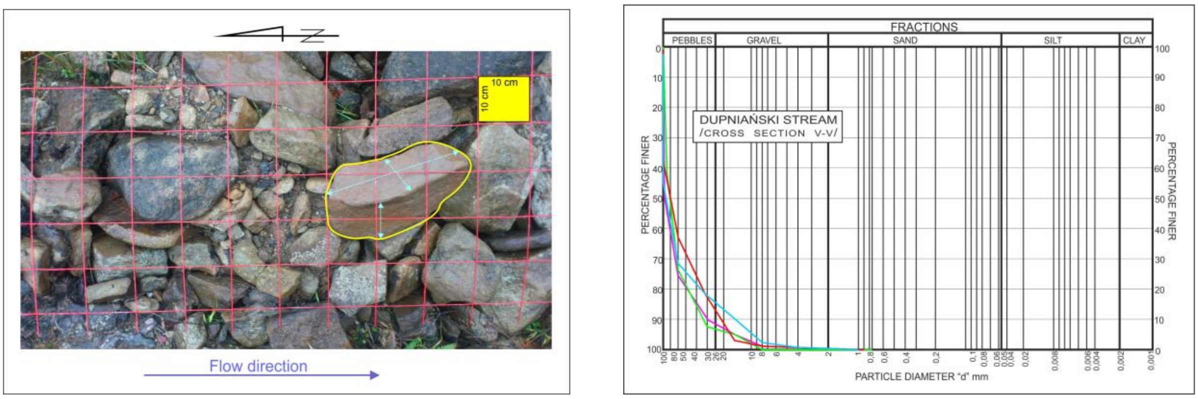

Figure 2: A - Example of measured bedload, B – cumulative frequency graph showing relative size of stream bed material above LWD step.

Conclusions

Sampled particles found above and below woody debris steps are built of both coarse- and fine grained sandstones and conglomerates. Coarser istebniańskie sandstones and conglomerates are more subject to self-abrasion. Therefore higher amount of finer material are found below steps within reaches where percentage of coarse grained particles occurred. Direction of LWD as well as their type (stem, stem with root system, stem with branches) influence the direction of coarser mineral material and hence the distribution of different type of channel forms above and below LWD steps. Consequently, distribution of LWD enforces the structure of stream channel morphology.

Acknowledgments

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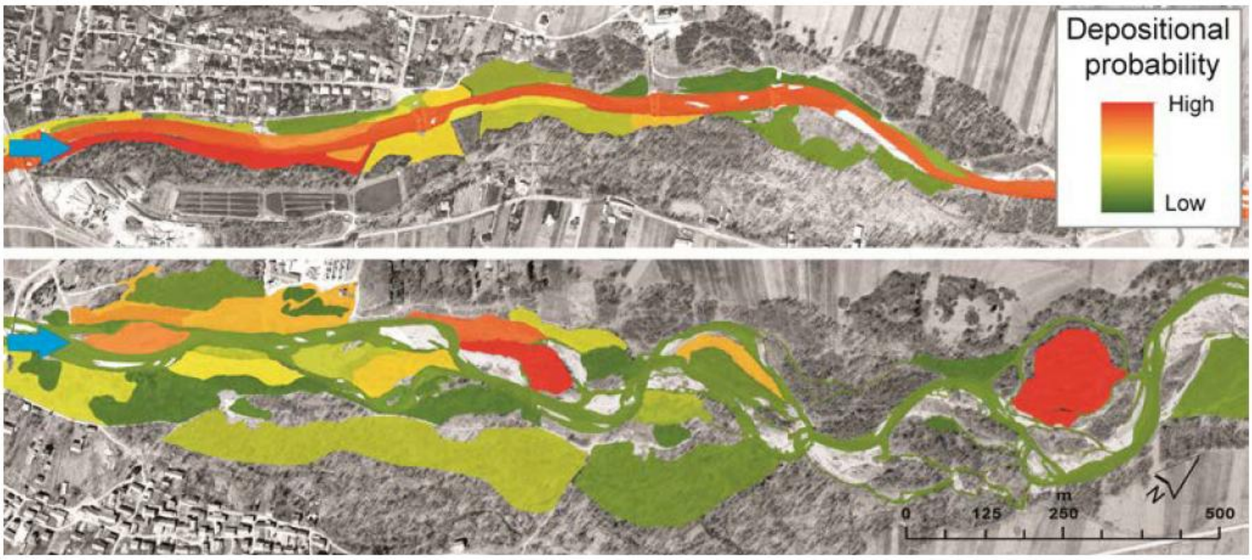
TOPIC 3 – Techniques for wood monitoring and modeling

Keynote speaker: **Hervé PIEGAY**

Presentation title: Wood is good but it moves! Associated problems and research issues

Short presentation

Over the last 3 decades, significant contributions worldwide have demonstrated the ecological interest of wood in rivers. Following these findings, wood introduction has been promoted in different countries as restoration measures and different state agencies reduced channel clearing practices to conserve these habitats. One of the key questions is now to bettern understand what is the risk associated with wood in rivers, considering the wood is moving downstream and can be trapped by obstacles or infrastructures, form jams, increase flood risk and damage infrastructures. This opens fondamental questions still unexplored both in term of hydrology and hydraulics dealing with wood budgeting and discharge as well as wood introduction, movement and deposit. These emerging questions are approached with different techniques from field monitoring and tracking to physical and numerical models.



Map of the probability of wood deposition in single-thread reach (upper) and multi-thread reach (lower) of the Czarny Dunajec for a frequent flood (1.2-year flood with a peak discharge of 28 $m^3 \cdot s^{-1}$)

(In: *Exploring wood dynamics in contrasting river morphologies: a numerical modelling approach. V. Ruiz-Villanueva, B. Wyżga, H. Hajdukiewicz, P. Mikuś, J. Zawiejska, M. Stoffel*)

An automatic video monitoring system for the visual quantification of driftwood in large rivers

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Abstract

In this work, we developed an automatic driftwood extraction software, based upon a statistical model. It aims at analyzing bigger and more exhaustive quantities of driftwood. We automatically characterized an already manually annotated database. We computed several indicators, such as True Positives (blocks that are both annotated and detected) and False Positives (blocks that are detected, but not annotated). When the volume of a piece of wood is greater than 15 Liters, the detection reliability is greater than 80%. Within certain areas of the image, we are also able to detect any size of blocks with a reliability greater than 70%.

Keywords: *driftwood; automatic extraction; video monitoring.*

Introduction

Driftwood in rivers impacts sediment transport, riverine habitat and human infrastructures. Quantifying this phenomenon can help improve our knowledge on fluvial transport processes. We are especially interested in large wood in fairly large rivers. Several means of studying driftwood exist, amongst which RFID sensors tracking, photo and video monitoring. In this work, we are interested in the latter, supposedly being easier and cheaper to deploy. However, video monitoring of driftwood generates a huge amount of images and manually labeling it is tedious. Automating such a monitoring process seems relevant. Yet, this specific task is largely unexplored in the field of computer vision, and more precisely automatic video analysis.

Study Elements

Figure 1: Location (left) and output (right) of our driftwood-monitoring camera.

We installed a video camera at the riverside of a gauging station on the Ain River, a Piedmont river in France with a catchment of 3500 km² (Figure 1). A human operator manually annotated several floods, by randomly chosen 15 minutes video sequences. For each visible woodblock, the operator selected the best view, and drew a rectangle (bounding box) around it. He then annotated the following frame in the same fashion, thus acquiring knowledge about the woodblock's characteristics and motion (MacVicar and Piégay, 2012). This annotated database establishes ground-truth. We aim at automatically producing information as close as possible to the ground-truth, with minimal human intervention or tuning.

Algorithm

We developed a tool that automatically characterizes a video stream. It is based upon a statistical model and combines static, dynamic and spatial data (Ali et al., 2014). First, we read each frame individually, and set a probability level for each pixel value. A static probability mask answers the question "is this pixel likely to belong to a wood-block, given its color and intensity?". A second, dynamic probability mask, analyzes each pixel's recent history. It answers the question "is this pixel likely to represent a woodblock now, given its past aspect?". Combining both masks highlights wood blocks rather than water. We further aggregate highlighted pixels into connex components, and match them from frame to frame. If we are able to track a component on several video frames, and if its motion is compatible with what we expect driftwood to do, we classify the component as a wood block. With this method, we obtain a set of views for each wood block, both spatially and temporally located. Segmented wood objects are further described with the help of a skeleton-based approach. This helps us automatically determine the object's characteristics for each view, in metrics terms.

Evaluation

In order to evaluate the performances of our algorithm, we automatically characterized an already manually annotated database. We computed several indicators. True Positives (TP) refer to blocks that were both annotated and automatically detected; False Positives (FP) to blocks that were detected but not annotated; False Negatives (FN) to blocks that were annotated but not detected. The higher the TP rate and the lower FP and FN rates, the better the software performs. We are also interested in analyzing such rates accordingly to block size and location: is the algorithm more robust with bigger blocks, in which area within the frame, etc. Below (Figures 2 and 3) are two sets of plots that show our first performance indications. On the right side of the image, where turbulent structures caused by the pile bridge upstream are weaker, detections are the trustworthiest: we are then able to detect any size of blocks (less than 2 Liters) with a reliability greater than 70%. Results also show that, as expected, bigger blocks are better detected. When the volume of a piece of wood is greater than 15 Liters, the detection reliability is greater than 80%. Big blocks can be overseen in the far end of the image though, mostly because they are only a few pixels wide. A further analysis of FP cases revealed that some of these cases are actually wood blocks; the human operator probably missed them because of their rather small size.

Discussions and Conclusions

Overall, results suggest that automatic video monitoring of rivers is a promising field. We believe that in a near future, it will be possible to pursue studies on driftwood based on the use of automatic video monitoring. A fair number of potential improvements exist, such as better exploiting the localization of detections. We plan on conducting more experiments, within a larger scope (various flow conditions, no-flow situations, windy situations, etc…). Further studies should focus on conducting evaluations with images from other locations, in order to ensure that our algorithm is not too specific regarding our first installed camera. They should also concentrate on how reliable our wood size measurement system is. Such experiments can also lead to a better understanding on how to locate and calibrate new monitoring cameras.

This work was partially supported by the project SedAlp: sediment management in Alpine basins, integrating sediment continuum, risk mitigation and hydropower, 83-4-3-AT

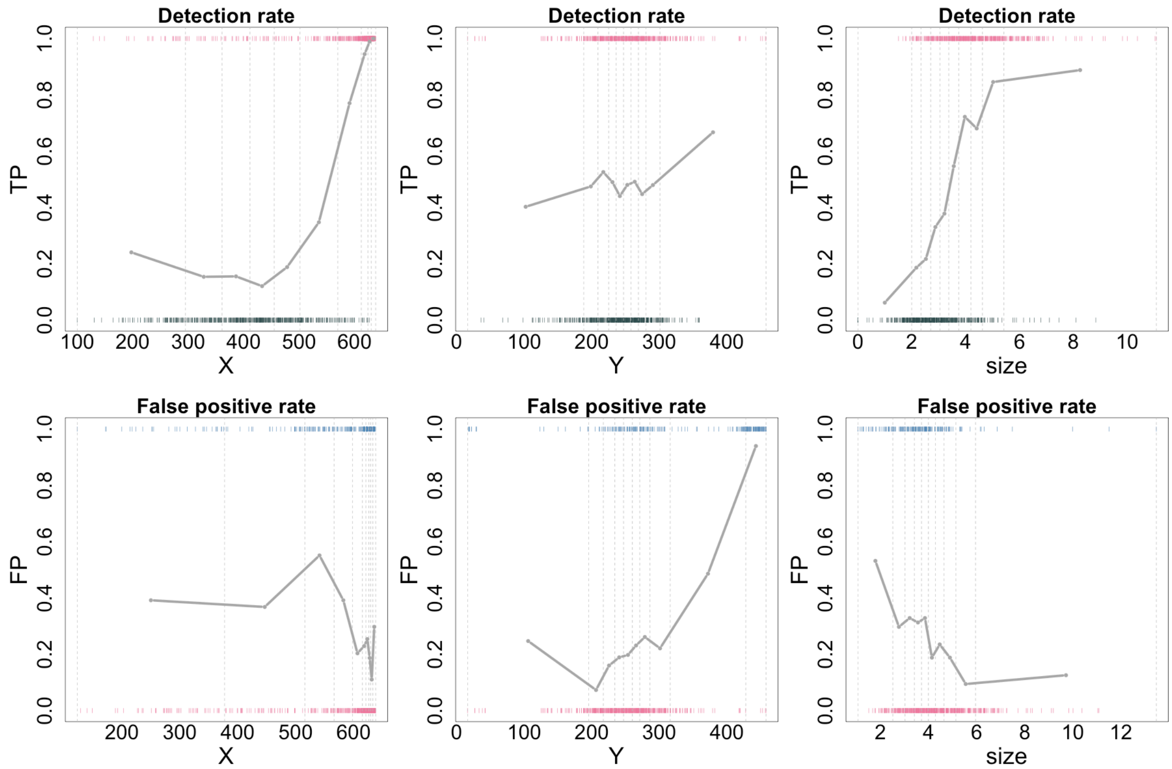

Figure 2: TP and FP rates for several factors. X axis is the horizontal axis, Y axis is the vertical axis (in pixels). The origin is the top left corner of the image. Size is an indicator based on the volume of the block, in cubic meters.

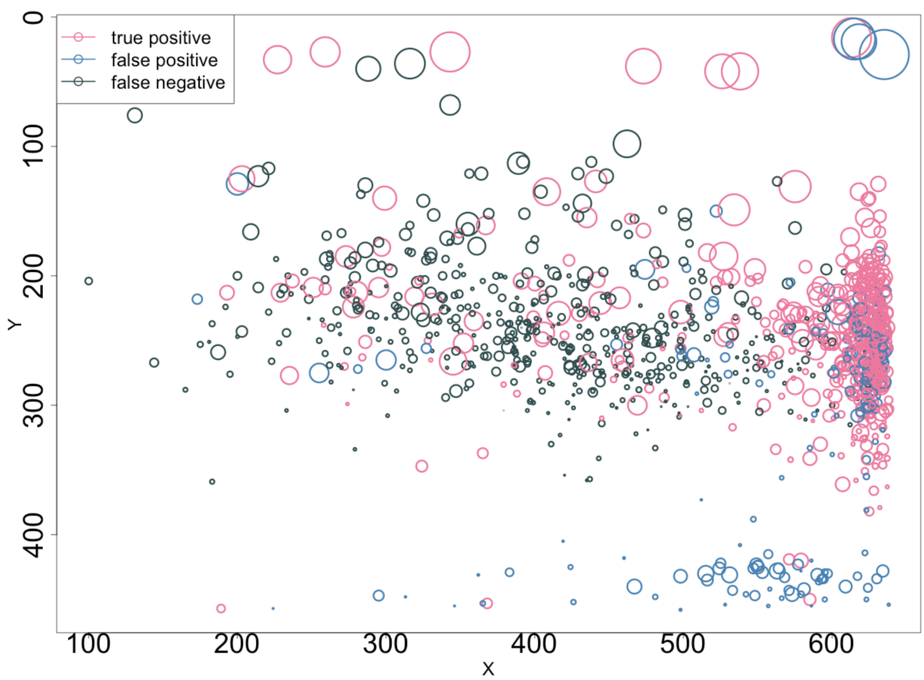

Figure 3: localization of TPs, FPs and FNs in the image. The size of a circle corresponds to the block volume. Flow runs from left to right

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Large wood delivery from buried dead wood: the use of Ground Penetrating Radar (GPR) to characterize excess pyroclastic deposits in the Blanco River, southern Chile

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Abstract

In steep forested headwater catchments, wood delivery to streams is dominated by snow avalanches, landslides and debris flows. In larger watersheds, tree mortality and bank erosion are relatively more important in recruiting large wood. However, explosive volcanic eruptions can fill river valleys with excess pyroclastic sediment and dead wood generating deposits several meters thick. Post-eruption fluvial reworking and channel adjustment erode these deposits and buried dead wood enters the channel. This is the case of the Blanco River in southern Chile, which was severely affected by the 2008 Chaitén volcanic eruption. In order to characterize the stratigraphy of these deposits and the signature of buried dead wood, geophysical surveys were performed based on the Ground Penetrating Radar (GPR) technique. Preliminary results indicate that the GPR technique was able to describe the internal morphology and structure of thick volcanic deposits along the Blanco River and identify buried dead wood pieces. Future studies will be oriented to improve the characterization of the volcanic deposits through high resolution subsurface mapping by means of 3D surveys and spectral analysis of the reflections, which will allow calculating spatial location and volume of buried dead wood

Keywords: *Ground Penetrating Radar; Dead wood; Pyroclastic deposits: Blanco river; Chile.*

Introduction

Large wood (LW) delivery to streams is an important geomorphic process (Martin & Benda, 2001; Reeves et al., 2003). In steep, forested headwater catchments, avalanches, landslides and debris flows are the dominant LW delivery agents. In larger watersheds tree mortality and bank erosion are relatively more important in recruiting LW (Martin & Benda, 2001; Reeves et al., 2003). However, in volcanic areas, the process of wood delivery is poorly understood. This is because explosive volcanic eruptions can fill river valleys with excess pyroclastic sediment and dead wood, generating complex deposits several meters in thickness. Post-eruption channel adjustments erode these deposits and buried dead wood is delivered into the stream networks (Ulloa et al., 2015).

Since external visual identification of buried wood is not possible, electromagnetic geophysical surveys using Ground Penetrating Radar (GPR) appear as a possible solution for studying the internal morphology and structure of thick volcanic deposits (Gómez et al, 2008; Jara, 2015). GPR has been used to clarify the geomorphologic characterization and assess the evolution of the sedimentologic conditions. In studies aimed at detecting root patterns and biomass of living trees, GPR has proven to be a rapid and noninvasive technique compared with traditional methods that are highly destructive and non-repeatable (Butnor et al., 2001; Gómez et al, 2008; Satriani et al, 2010; Gertisser et al, 2012; Borden et al, 2014). However, to date

GPR has not been used (to our knowledge) to estimate the volume of dead wood buried in volcanic deposits.

Here we examine LW in pyroclastic material in the Blanco River in southern Chile, a site that was severely affected by the 2008 Chaiten volcanic eruption. Post-eruption fluvial reworking and channel adjustments have eroded these deposits and buried dead wood enters the channel along the network (see Fig. 1-A). The objectives of this study are to: (a) Examine the potential for GPR to identify buried LW in ash deposits, and (b) Obtain the GPR signature of wood buried in these sediments. This preliminary analysis is intended to provide insights on the potential of using GPR to estimate the volume of LW buried in the deposits in volcanic settings.

Study Area

The study concentrates in a deposit of sediments of volcanic origin located in the right margin of the Blanco River, immediately upstream from the city of Chaiten. Detailed information of the Chaiten volcanic eruption and sedimentologic processes in the Blanco and location of the study area can be found in Ulloa et al. (2015).

Methodology

The GPR technique was applied along the edge of near-vertical gully wall. The gully provided access to characterize volcanic deposit layering and stratigraphic conditions. Four wood pieces with different but well known diameters and a metallic bar were inserted into the volcanic deposit at specific depths, in order to calibrate the GPR velocity parameters of the soil media. The wood pieces and the metallic bar were geo-referenced with a differential GPS. A RAMAC X3M GPR with 250 and 500 MHz shielded antennas was carried along the edge of the gully in order to generate a radargram (defined here as a bi-dimensional image of the subsoil).

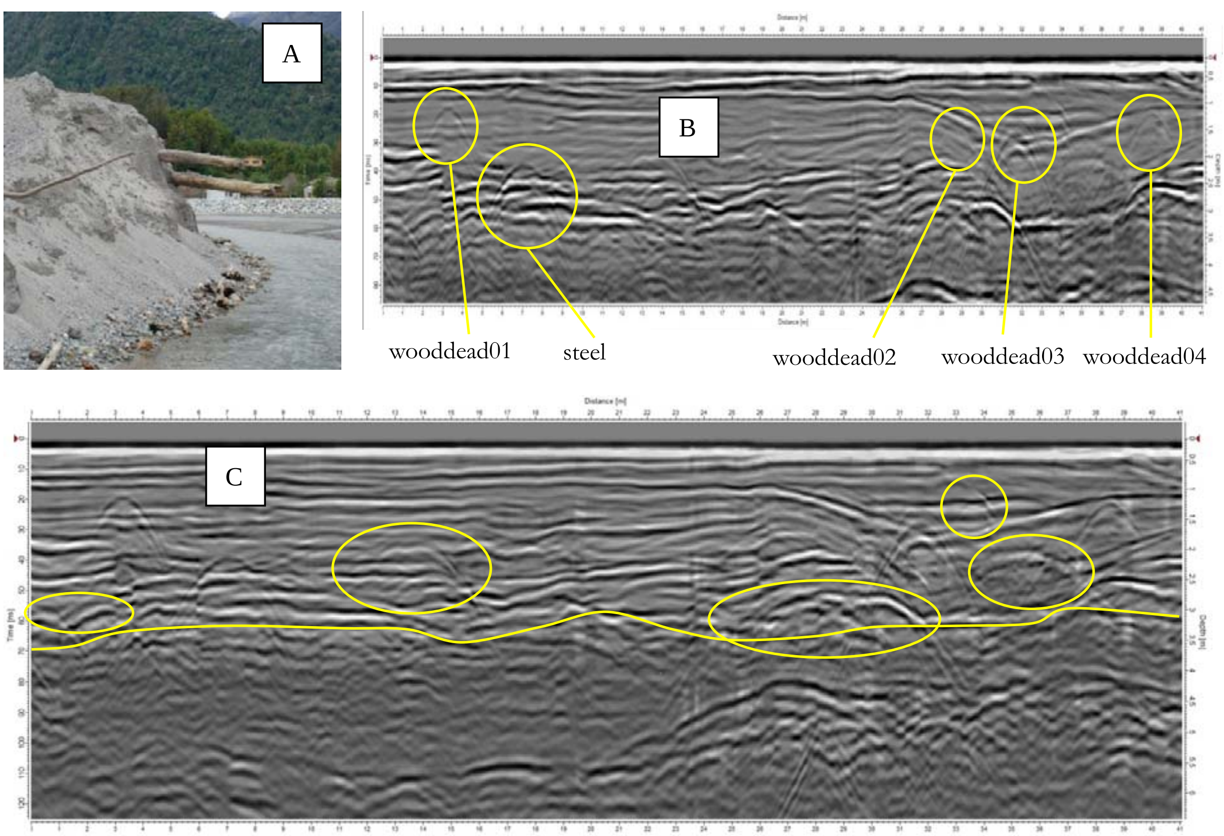

Figure 1: Buried dead wood exposed by channel reworking and bank erosion (A); radargram of the survey showing the buried dead wood (B), and the complete radargram (C).

Results

GPR radargram analysis using the 250 MHz shielded antenna yielded the best resolution and a depth penetration of 6 m. We found good resolution-parabolic reflections generated by the pieces of dead wood embedded in the sediments (Fig. 1-B). At position X = 7.2 m we observed important reflections generated by the metallic bar, in which the propagation speed was set to v = 100 m /μs. Longitudinal location and depth of the reflections coincided with the purpose-buried wood pieces, allowing the establishment of the dead wood signature for the pieces with different diameters.

Other reflections were also observed; their specific signatures corresponded to the buried wood pieces (Fig.1-C). At three meters deep, a clear stratigraphic change was observed which corresponded to the interface between the recent volcanic sediments and the soil surface from before the eruption (Fig. 1-C).

Discussion and Conclusions

This work shows the efficacy of the method to study the internal structure of the post- eruption sediments. GPR appears as a fast, economical and non-invasive way to characterize the buried LW in volcanic deposits. In this sense, it is possible to create 3D profiles using high resolution mapping of the sub-surface with precise location and volumetric characterization of buried dead wood. Our future work will explore high resolution subsurface mapping via 3D surveys and related spectral analysis to obtain dead wood volumes and estimates of sediment stratigraphy associated with geomorphic changes.

Acknowledgments

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Log transport and deposition during a flood in a mountain river: tracking experiment using radio telemetry

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Abstract

Tracking experiment with logs tagged with radio transmitters and 1D hydraulic modelling were used to investigate differences in depositional conditions and the length of transport of large wood during a 20-year flood between channel sections of different morphology in the Czarny Dunajec River, Polish Carpathians. A majority of the tagged logs were deposited on gravel bars and vegetated islands, a smaller proportion on the floodplain and some within the low-flow channel and on river margins. The number of retained logs increased and the length of log displacement decreased from a deeply incised river section through a channelized section to a wide, multi-thread section. River cross-sections with deposited logs were typified by significantly greater flow area and width and lower mean flow depth, mean velocity, unit stream power and bed shear stress than cross-sections without wood deposits.

Keywords: *log displacement, radio tracking, flood, river morphology, hydraulic modelling, mountain river*

Introduction

Complex interactions among large wood, channel form and flow hydraulics cause that many aspects of wood dynamics in wide mountain rivers are still insufficiently understood. Recognition of controls on the length of wood transport during flood events and preferential sites of wood deposition is crucial for the evaluation of flood risk related to wood accumulations in mountain rivers (Kundzewicz et al., 2014) and possibilities of the restoration of modified mountain rivers using spontaneously recruited large wood (Wyżga & Zawiejska, 2010). In wide mountain rivers, large distances of wood displacement during flood events, considerable dimensions of their channels/active zones, and aggregation of a large proportion of wood pieces into jams make tracking of individual wood pieces especially difficult. In recent years a few types of remotely tracked electronic tags of unique signal frequency were used to investigate wood dynamics in such rivers (MacVicar et al., 2009; Schenk et al., 2014; Ravazzolo et al., 2015). In this work we present results of a tracking experiment with logs tagged with radio transmitters, that was performed during a 20-year flood on the Czarny Dunajec River, Polish Carpathians.

Study area

The Czarny Dunajec is a fifth-order river in the Polish Carpathians. It rises at about 1500 m a.s.l. in the high-mountain Tatra massif and in the Tatras foreland, it flows through a non-cohesive alluvial plain in a channel of varied morphology. This morphological variability mostly reflects human disturbances that affected some sections of the river in the 20th century: channelization and gravel mining-induced channel incision. The tracking experiment was performed in a 17 km-long river reach without significant tributaries, where the previous study on the retention of large wood was perfomed by Wyżga and Zawiejska (2010). Along the whole reach, the river width is larger than the height of riparian trees (Wyżga et al., 2015). In the upper part of the reach the channel is deeply incised and moderately narrow, in the middle part it is narrow and regulated with a number of concrete drop structures, and in the lower part the river flows in a wide, multi-thread channel. With almost tenfold variation in the channel/active zone width (Wyżga et al., 2015), the reach is typified by considerable variability of hydraulic conditions. The forest growing along the river banks and on wooded islands consists of alder and willow species.

Materials and methods

In May 2014 a flood occurred with the peak discharge of about 20-year return period. Before the flood, radio transmitters were installed inside 30 alder logs 3 m in length and about 20 cm in diameter. On the rising limb of the flood the tagged logs were placed into the river at three locations: 10 at the beginning of the incised river section, 10 at the beginning of the channelized section and 10 about 1 km upstream from the beginning of the multi-thread section. After the passage of the flood, we searched for the logs using antennas and signal receivers. The position of each found log was determined with a GPS receiver. In the subsequent months cross-sections running through the positions of log deposition were surveyed. Channel slope in the vicinity of the cross-sections and their morphology in the river and floodplain areas were measured with level. Grain size of the surface bed material in low-flow channels and gravel bars was determined with the Wolman method and used to calculate channel roughness. Roughness coefficients for parts of the floodplain with different vegetation cover were also determined. Similar data were also collected for a number of river cross-sections that generally lacked deposition of large wood. Peak discharge of the flood was estimated for all the cross-sections based on the data from three gauging stations on the river and catchment area to each cross-section. Finally, 1D hydraulic modelling was performed with HEC-RAS software for the peak flow of the flood in the river cross-sections with deposited tagged logs and without wood deposition.

Preliminary results

We recovered 24 (80%) out of the 30 logs placed into the river. Of these logs, 3 (12.5%) were deposited in the channel, 3 (12.5%) on channel margins, 5 (21%) on the floodplain and 13 (54%) on gravel bars and vegetated islands. Only 1 log was retained in the incised river section, 5 in the channelized section, 17 in the multi-thread section and 1 in the channelized river section downstream of the unmanaged, multi-thread section. Significant differences (Kruskal-Wallis test, $p = 0.001$) in the travelled distance existed among the logs delivered to the river at the three locations (Figure 1). Logs delivered to the river at the beginning of the incised section travelled between 3.7 and 14.6 km, with the mean displacement by 11.4 km. Logs supplied at the beginning of the channelized section travelled between 0.03 and 9.0 km, with the mean travel distance of 6.4 km. Finally, logs delivered to the river close to the wide, multi-thread section were displaced between 1.2 and 7.6 km, 2.6 km on average.

Results from 1D hydraulic modelling of the peak flow of the flood revealed differences in hydraulic conditions between river cross-sections with deposited logs and cross-sections lacking wood deposits. The former were typified by significantly greater cross-sectional area of the flow and flow width and lower mean flow depth, mean velocity, unit stream power and bed shear stress than the latter. Cross-sections with deposited logs and those without wood deposits were also clearly distinguished by a principal component analysis. The first axis of the PCA, describing the differentiation of the above mentioned variables, explained the most of the total variance in hydraulic parameters among the surveyed cross-sections.

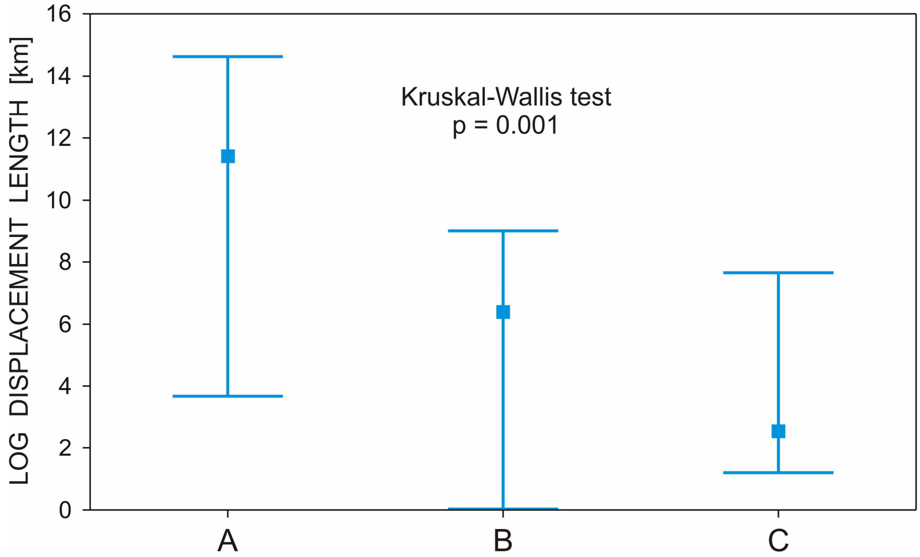

Figure 1: Displacement length of the logs placed into the river at the beginning of the incised river section (A), at the beginning of channelized section (B), and 1 km upstream of the beginning of the wide, multi-thread section (C).

Conclusions

The experiment confirmed efficiency of the tracking approach in exploring wood dynamics in wide rivers – by using logs of the same dimensions during a single flood event, we were able to compare transport and depositional conditions for large wood in different river morphologies. Findings from the previous wood inventory (Wyżga & Zawiejska, 2010) were confirmed, indicating that in wide mountain rivers wood can be transported long distances in a narrow, single-thread channel, whereas it is preferentially deposited in a wide, multi-thread channel. The hydraulic modelling provided physical justification of these differences in wood behaviour in the distinct channel morphologies.

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Exploring wood dynamics in contrasting river morphologies: a numerical modelling approach

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Abstract

The aim of this contribution is to explore the main factors controlling large wood dynamics in the Czarny Dunajec River in Poland, combining direct field observations, 2D numerical modelling and GIS. Numerical modelling is a powerful tool to analyse different aspects that govern wood deposition, because models can be used to run scenarios and can be analyzed fully at any spatial and temporal scale. We used a numerical model to simulate flood events of different magnitude and to analyse wood deposition in two different river reaches. Preliminary results provide information about sites of preferential wood deposition, wood retention capacity and their relationship with river morphology. We find contrasting patterns regarding wood retention capacity in the single-thread and the multi-thread channels. We also observe that the deposition of wood is not static but dynamic and significantly depends on the hydrological regime.

Keywords: *In-stream wood, numerical modelling, flood, river morphology, Czarny Dunajec*

Introduction

Exploring in-stream wood (i.e. large wood, LW) dynamics still remains difficult because of the complex interactions among wood recruitment, channel form and flow hydraulics (Wohl & Cadol, 2011). Improving the understanding of wood retention and distribution is therefore important given the geomorphic and ecological importance of wood in rivers.

A variety of techniques have been employed to measure wood retention: detailed mapping of the locations of wood pieces (Elosegi et al., 1999), remote sensing (Lassettre et al, 2008; Bertoldi et al., 2013), wood tagging and tracking (MacVicar et al., 2009) and physical experiments (Bertoldi et al., 2014). This contribution shows a relatively new approach to predicting and analysing wood dynamics by combining numerical modelling and field measurements. A wide range of quantitative information about wood transport and deposition can be obtained from the use of numerical modelling together with the proper assessment of boundary conditions and validation based on field data. In this work we combine the numerical simulation of wood transport and deposition with field observations to analyse wood dynamics along the mountainous Czarny Dunajec River in Poland. As numerical modelling was run here in a multi-run mode, the results can be analysed in a probabilistic manner. Combining results of the numerical modelling with information obtained from field surveys and tracking of wood in the river enables us to analyse main factors controlling wood transport, depositional patterns of large wood that may result from the occurrence of floods of different magnitude, impacts of flood sequencing or relationships with flow regime and discharge.

Study Area

The Czarny Dunajec River drains the Inner Western Carpathians in southern Poland. It rises at about 1500 m above sea level (a.s.l.) in the high-mountain Tatra massif, with the highest peak in the catchment at 2176 m a.s.l. In the studied section within the Tatra Mountains foreland, the river is a fifth-order watercourse with mean annual discharge of 4.4 $m^3 s^{-1}$. Characteristic features of the hydrological regime of the river are low winter flows and floods occurring between May and August due to heavy rains, sometimes superimposed on snow-melt runoff. The studied section is at an altitude of 670 to 626 m and is 5 km long. The riparian forest is composed of alder and willow species with predominating young, shrubby forms of *Alnus incana, Salix eleagnos, S. purpurea* and *S. fragilis,* less frequent stands of *older A. incana* trees and occasional *S. alba* trees.

The high variability of the river width and morphology enabled us to distinguish two different reaches representing single-thread, partially channelized (R1) and unmanaged, multi-thread (R2) channel morphologies (Wyżga and Zawiejska, 2010).

Materials and methods

The 2D numerical model proposed by Ruiz-Villanueva et al., 2014 simulates large wood transport together with the hydrodynamics by means of a Langrangian discretization. The method couples flow variables calculated with the hydrodynamic module to update the position and velocity of tree logs at every time step. It considers incipient wood motion, performing a balance of forces (the gravitational force acting in a downstream direction; the friction force in the direction opposite to flow; and the drag force, acting in the flow direction) acting on each single piece of wood (assuming logs as cylinders). An additional term in the 2D Saint Venant equations is included in the flow model as an additional shear stress at every finite volume, resulting from the presence of logs.

Data from the Koniówka water-gauge station was used to characterise the inlet flow. Flood discharges of given recurrence interval were calculated for running different inlet discharge scenarios and the available rating curve was used to calibrate roughness (Manning's n). Roughness coefficients were obtained from the delineation, in the channel and the flooding areas, of homogeneous land units in terms of their roughness (roughness homogeneous units; RHU) and using in situ measurements of sediment size in selected transects. All RHUs delimited in the field were digitized using a GIS and a possible range of roughness values was assigned to them applying different empirical equations in the transects. Different discharge ranges were run to calibrate the obtained Manning roughness values for high and low flows, and estimate the obtained error.

Assuming that wood recruitment is only occurring upstream of the studied reaches, a number of logs per minute was defined to enter the simulation. To characterise each piece of wood entering the simulation, we established ranges of maximum and minimum lengths, diameters and wood density. Stochastic variations of these parameters together with log position and angle with respect to the flow were then used. The scenarios were designed to be physically reliable and in agreement with the characteristics of the study river.

Preliminary results

Preliminary results provided information about wood deposition, transport capacity and relationships with flood magnitude and river morphology. We observed that wood transport capacity differs significantly between both reaches ($p = 0.001$). It is higher in the single channel than in the multi-thread one for all the flood scenarios and log types considered. We also identified preferential sites for deposition (Figure 1). Combining all these scenarios will allow to estimate wood deposition probability.

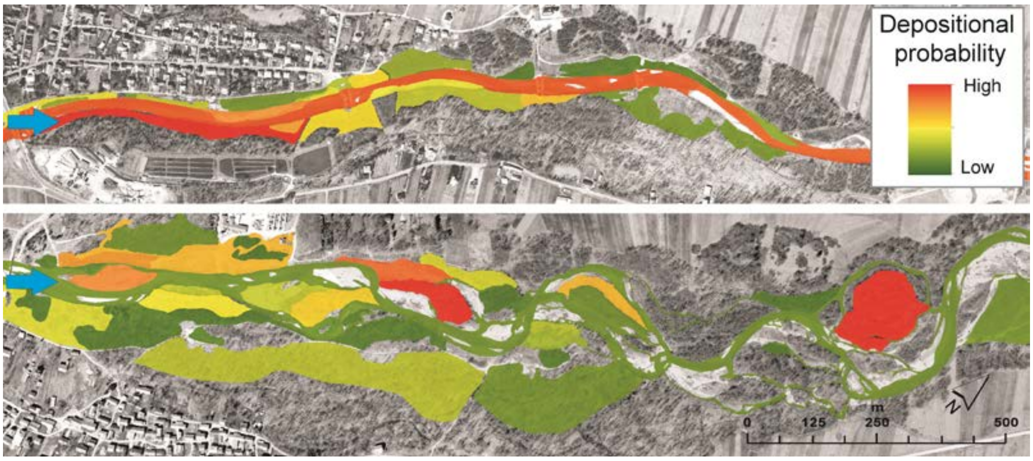

Figure 1: Map of the probability of wood deposition in single-thread reach (upper) and multi-thread reach (lower) of the Czarny Dunajec for a frequent flood (1.2-year flood with a peak discharge of 28 $m^3 \cdot s^{-1}$).

We hypothesized that a major control on wood deposition is the relative elevation of depositional sites above low-flow water surface and lower channel bank. It was compared between particular discharges and between reaches. Results confirmed that deposition elevation changes significantly with flood magnitude (Figure 2).

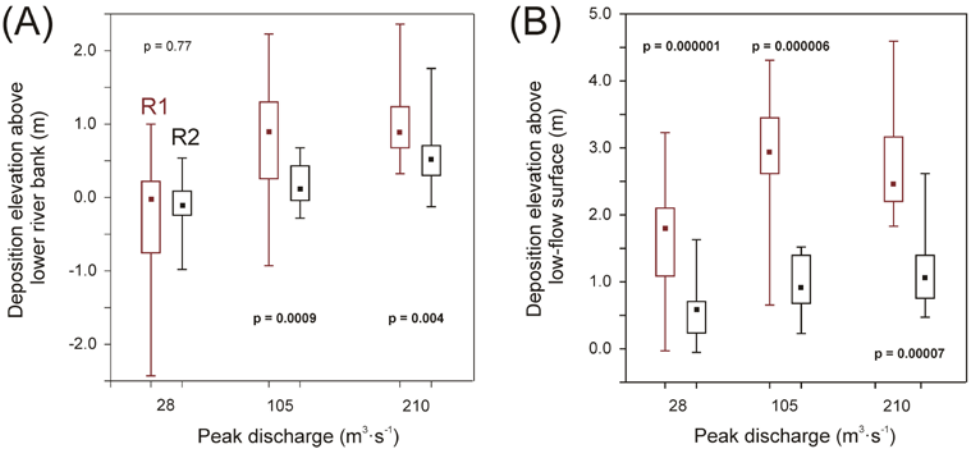

Figure 2: Elevation of wood deposition in relation to the lower river bank (A) and the low-flow water surface (B) in reach 1 and reach 2. Statistical significance of differences between the reaches at different peak discharges, determined by Mann-Whitney test, is indicated.

Acknowledgments. This work is supported by FLORIST Project (Flood risk on the northern foothills of the Tatra Mountains), PSPB no. 153/2010 from the Swiss Contribution.

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Implementation and validation of large wood analysis for wood budgeting in a semi-alluvial river, the Saint-Jean River, Gaspésie, Canada

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Abstract

The semi-alluvial rivers of the Gaspé Peninsula, Québec (Canada), recruit and transport vast quantities of large wood. The rapid rate of channel shifting due to high-energy flows and non-cohesive banks allows the recruitment of large quantities of wood that in turn greatly influence river dynamics. The delta of the Saint-Jean River has accumulated a flux of wood since 1960, creating frequent avulsions, and now has a wood raft of more than 3 km in length. The *Raft* of the Saint-Jean River on the Gaspé Peninsula, Québec, Canada is an exceptional amount of wood that is unusual but natural. The river has complex large-wood dynamics that promote the formation of large wood jams in the river delta. The jam configuration allows a unique opportunity to apply a wood budget at the scale of a long river corridor and to better understand dynamics of large wood in river. A wood budget includes the evaluation of wood volumes (i) produced by bank erosion (input), (ii) still in transit in the river corridor (deposited on bars or channel edges), and (iii) accumulated in the delta (output). The budget is based on an analysis of aerial photos dating back to 1963 as well as surveys carried out between 2010 and 2014, all of which were used to locate and describe large wood accumulations along a 60 km river section. Understanding the interannual large wood dynamics in the Saint-Jean River can assist river managers determine sustainable solutions for the issue of wood rafts.

Keywords: *large wood in river, wood transport and mobility, large wood jam, wood budget, watershed scale.*

Introduction

Pioneering works on large wood (LW) in river have described historical wood accumulations in North American rivers at the time of European colonization. The *Great Raft* of the Red River for example, was an enormous wood accumulation that was more than 300 km long with a long residence time during the 19th century (McCall, 1988). In modern times, such large rafts are unusual because of river management (Wohl, 2014), but there are a few documented cases in reservoirs when a dam blocks the transfer of wood downstream (Moulin and Piégay, 2004). Over the last decades, most studies on large wood dynamics were carried out in small streams (Seo *et al*., 2010), and there is a clear need to develop management tools and strategies to deal with LW in medium to large rivers (Kasprak *et al*., 2012) and in rivers of cold areas (Boivin *et al*. 2014). The Saint-Jean River on the Gaspé Peninsula in Québec, Canada, represents an ideal study area to explore challenging issues related to LW dynamics for management (Boivin *et al*., 2015). The river and its managers face several impacts from LW that affect river morphodynamics and biological integrity: three massive rafts together block more than 3 km of channels in the river delta (Fig.1).

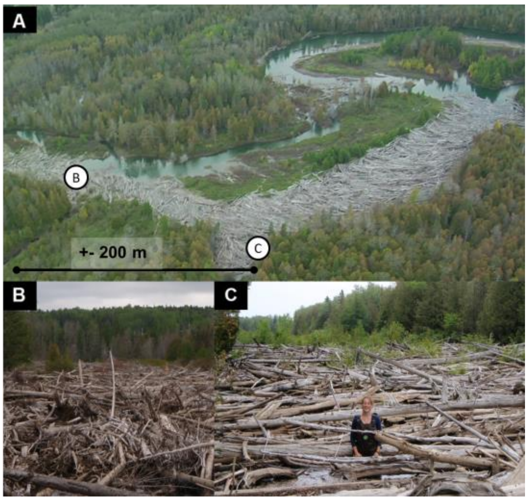

Figure 1: Raft in the estuary of the Saint-Jean River. (A) Upstream part of the raft in the central channel in 2011. (B) and (C) Part of raft in the central channel and position where the pictures were taken in (A).

Study Area

The Saint-Jean River is located in the eastern part of the Gaspé Peninsula in Québec, Canada, in the physiographic region of the Appalachian Mountains. Elevations range from 700 m in the headwaters to sea level, where the river flows into the Bay of Gaspé through a delta that is subject to daily tides. It drains an area of 1130 km^2 and has an approximate length of 130 km and an average annual flow of 30 m^3/s. Well defined spring floods characterises the hydrological regime of the river. Mean annual snowfall is 371.8 cm while mean annual rainfall is 779.2 mm at the nearby Gaspé station. The Saint-Jean River is a dynamic gravel-bed river encompassing three specific river styles (meander, straight and anastomosed style).

Materials and Methods

The lower 60 km river corridor accessible from the road was surveyed by canoe to locate and characterize all LW accumulations within the active channel width between 2010 to 2013. Annual surveys allowed locating and describing more than 1000 LW jams and 2000 individual's pieces within the river corridor. For each LW accumulation, the shape, the position, the volume, the number of trunks, the orientation, the decay stage and the mass were measured. Combined with the raft accumulation patterns in the delta (Boivin et al., 2015), this dataset provides a unique opportunity to quantify a wood budget to better understand the controlling factors (Fig. 2). The wood budget includes the evaluation of wood volumes produced (Vi: input), still in transit in the river corridor (Vt: deposited on bars or channel edges) and accumulated in the delta (Vo:

output) (Fig. 2).The repeated surveys allowed defining the morphological characteristics as well as the jam configuration that promote wood mobility and deposit. The repeated surveys also allowed examining the transport rates from one year to another for specific river sections. Airborne and ground photo/video images are used to evaluate the volume introduced and determine the transport rates.

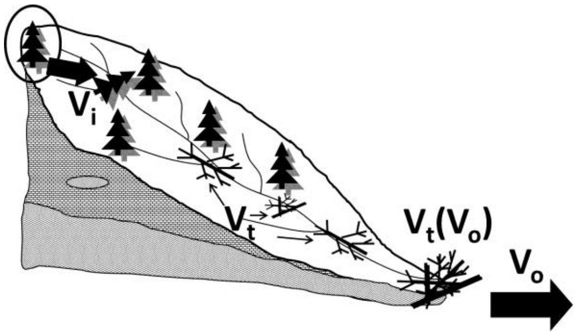

Figure 2: Conceptual model of large wood budget at the watershed and corridor scale

Results

Wood volume input (Vi)

This analysis examined the longitudinal distribution of eroded floodplain areas along the corridor of the Saint-Jean River for a 40-year period (Fig. 3). Between 1963 and 2004 and between 2004 and 2013, only lateral migration and avulsion processes were observed. No landslide occurred on the entire river corridor, and we assume that most wood recruitment result from these two dominant processes. Two sections showed strong floodplain erosion, with average eroded areas of 7 600 m^2/km and 14 500 m^2/km for sections PK1-10 and PK30-55, respectively, while the most highly eroded area was PK54 (54 700 m^2/km). Overall, a floodplain area of more than 482 000 m^2 (±5 000 m^2) was eroded over the 40-year period, 83% of which was in the upstream section.

Wood in transit (Vt)

The number of LW accumulations has changed significantly from 2010 to 2013 caused by extreme hydro-meteorological event in December 2010: 233 (2010), 973 (2011;+ 318%), 947 (2012; -3%) and 765 (2013; -19%). The number of LW in the river corridor has increased significantly too: 11,716 (2010), 17 235 (2011;+ 47%), 19,235 (2012 ;+12%) and 21 962 (2013;+14%). Finally, wood volume also increased during this period 5950 m^3 (2010), 9454 m^3 (2011;+ 61%), 10,429 m^3 (2012;+10%) and 11,274m ^{3} (2013;+ 8%). The volume per kilometer analysis shows four reaches (reach 1, 4, 5 and 6) with higher volumes per kilometer (Fig. 3). Reach 1 shows the largest increase from 1403 m^3/km at 4206 m^3/km between 2010 and 2013. Reach 2 and 3 have lower volumes and low variation between the 4 years of monitoring.

Wood accumulated in the delta (Vo)

Historical imagery's analysis in Saint-Jean illustrates the complex dynamics of LW accumulation since 1963. From the aerial photos taken between 1963 and 2013, it can be estimated that more than 24 700 m^3 of LW had accumulated within the three main branches in the delta. This gives an average wood accumulation of 494 m^3 per year. In 2013, the three main channels (north, central, and south) are completely obstructed by rafts and a new channel has formed since 2012 by redirecting flow to the southern part of the delta.

Geomorphological analysis

Three units and six reaches appear in the analysis of river dynamics and large woods in river dynamics in the Saint-Jean River (fig. 3). Unit A (PK 0-10, reach 1) where the LW accumulation volumes were higher, but where unit stream power (rate of potential energy per unit channel width) and erosion rates was low. Unit B (PK 10-30, reaches 2 and 3) where the volumes of LW is low, the rate of erosion and accumulation benches are practically absent and with the highest unit stream power. Finally, Unit C (Pk 30-60, reaches 4-5 and 6) are the most dynamic portion of the Saint-Jean River corridor. Volumes of LW, erosion rates and bar surface accumulations are higher than other section, with specific powers that vary in these sections.

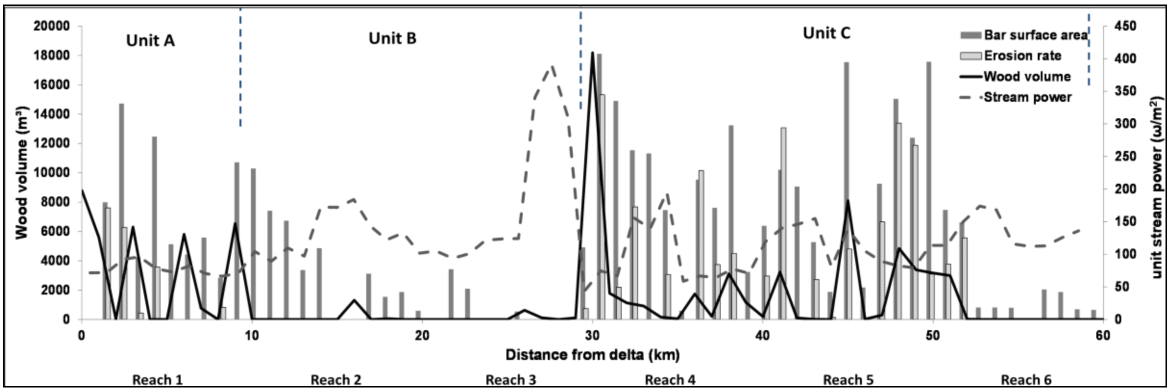

Figure 3: Geomorphological impacts (bar surface area, erosion rate and unit stream power) on LWJ dynamic.

Discussions and Conclusions

The raft of the Saint-Jean River on the Gaspé Peninsula represents an exceptional amount of wood for modern times—unusual, but natural—as shown by the presence of raft in 1845 (Blaiklock, 1845). Wood accumulation began in 1963, but raft size has been observed to strongly fluctuate on shorter time scales. The river is characterized by complex LW dynamics that promote the formation of LW jams in the delta. Our results show that almost all of the LW is produced by natural lateral migration and by river morphology (e.g., cutoff meanders). The case of the Saint-Jean River is an exceptional study site to apply and develop a LW budget. The analytical model developed from the wood budget and the understanding of wood dynamics can assist river managers in their decision making to determine possible solutions that include the production, transport and accumulation of LW in cold river.

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Timelapse imagery, crowdsourcing and wood transport on big rivers in the subarctic

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Abstract

Monitoring large wood in transport within rivers is a necessary next step in the development and refinement of wood budgets and is essential to a better understanding of basin-wide controls and patterns of large wood flux and loads. This study uses timelapse photography to monitor a network of large tributaries to the Mackenzie River in Northern Canada. Crowdsourcing was utilized to help categorize timelapse imagery by levels of wood transport. Wood discharge curves were generated and used to compare tributaries and develop thresholds for wood transport. Historic aerial imagery and repeat video mapping of river banks were used to determine historic variability in wood flux. Preliminary results suggest that both timelapse photography and crowdsourcing are excellent ways to acquire distributed data about wood flux on large spatial scales for entire transport seasons.

Keywords: *wood transport; timelapse; crowdsource; large river; subarctic.*

Introduction

Although many studies quantify, either in the field or via remote sensing, the potential stock of wood available for transport along streams and rivers (e.g. Abbe and Montgomery, 2003; Moulin et al., 2011), little effort has been employed in monitoring and quantifying wood in transport as it happens. The buoyancy of wood makes the use of imagery ideal for monitoring wood transport. Just as sediment gages are integral for developing basin-wide sediment budgets, wood gages, in the form of cameras, could be used alongside stream gages to generate wood transport data to inform basin-wide wood budgets. Previous attempts at generating wood budgets have focused on estimating recruitment volumes and changes in storage and then back-calculating wood export (Benda and Sias, 2003). However, this approach may be underestimating actual wood export by as much as a factor of ten (MacVicar and Piégay, 2012). Recently, Schenk et al. (2013) tracked individual logs in transport using radio telemetry and combined those results with data from aerial photographs and on-site wood surveys to develop the first basin-wide wood budget on the low gradient Roanoke River in North Carolina.

A first attempt at creating a wood transport curve used video monitoring of floods on the Ain River in France in 2011 (MacVicar and Piégay, 2012). Whilst video monitoring provides high temporal resolution data useful for computing rates of transport and fine scale relationships between wood and water discharges, timelapse photography allows a researcher to sample at broad spatial and long temporal scales. Investigations at broad scales that answer questions about basin connectivity are integral as river scientists attempt to quantify system resilience and make recommendations for managers in an increasingly uncertain future. Sampling at long intervals (minutes) is also extremely advantageous for studies with small budgets which seek to install networks of cameras to be left up for months. This is especially true for remote areas where access, travel costs, or project costs limit the practicality of video monitoring.

Crowdsourcing is a recent concept that asks a crowd (large group of people) via an online platform to voluntarily complete a task (Estellés-Arolas and González-Ladrón-de-Guevara, 2012). Crowdsourcing is especially suitable for analyzing timelapse photography because there are high volumes of data requiring simple categorization; a task that is still much easier for the human eye than a computer to complete accurately. An additional benefit of crowdsourcing is that it connects and engages citizens with scientific research.

This study calculates wood transport in large rivers and export of large wood to the Arctic from the Mackenzie Basin, Canada. Basin connectivity of wood transport, year to year transport variability and differences in transport thresholds between tributaries, and wood mobility related to river ice processes are discussed.

Figure 1: Stars indicate the location of timelapse cameras. The inset image shows my camera near Fort Smith, as well as a freshet "wood flood" which occurred July, 2011 with water discharge ~7200 m^3/s. At this location, summer flows typically range from about 3000 to 6000 m^3/s. The highest flow on record was 11200 m^3/s on May 5, 1974 and was associated with ice break up.

Study Area

This study was conducted in 2013 and 2014 in the Mackenzie Basin, a very large river basin that drains 20% of Canada. Figure 1 shows the location of cameras installed to monitor wood transport. The Mackenzie Basin is ideal for studying wood loads because its catchment is lightly impacted by development. It is one of the few regions left in the world where wood flux today is similar as it was before the Anthropocene.

Materials and Methods

Pictures of the river were taken every ten minutes and analyzed for wood. Crowdsourcing was used to categorize large wood seen in photographs into six categories: no wood, single piece, multiple pieces, clumped pieces, ribbons of wood, and carpet of wood. Wood discharge curves were then generated following the methods of Kramer and Wohl (2014). Crowdsourcing results were compared to digital analysis of change between photographs and a background photograph with no wood. In a unique zone of limited transport due to decreased conveyance through a section of bedrock islands, a 30yr record of repeat oblique aerial photography was used to relate change in wood storage to hydrology. On the Liard river, repeat video mapping along river banks during the study period was used to relate wood flux temporary storage of wood on river banks.

Results

Although most of the timelapse photography has yet to be analyzed, preliminary data from 2012 on the Slave River (10^3 cms, slope=10^{-2} m/km) suggest that a threshold relationship for wood mobility was located around 4500 cms, which is very close to a 4000 cms threshold required for mechanical ice break up identified by Beltaos and Prowse (2006). More wood is transported on the rising limb of the hydrograph because wood flux rapidly declines on the falling limb. Wood transport is the greatest in high water years that follow many years of lower flows. River ice processes play a large role controlling annual flux of wood from the Slave and other Northern rivers. Trees which fall into the river via bank failure or are stranded by high flows are routinely transported by ice jams and associated floods. During average flow years, most of the wood is transported during ice break up rather than freshet peaks. Crowdsourcing is a fast and accurate way to analyze lots of timelapse photography that has the benefit of engaging citizens in river science.

Discussions and Conclusions

There are many strengths to using timelapse photography to monitor wood fluxes and loads. It is a low cost, low maintenance, power efficient method. It can be used to extrapolate into data gaps, such as night time. It produces conservative, first order estimates of minimum wood loads. It also allows easy comparisons of wood flux to hydrographs on long spatial and broad temporal scales. However, it is good to keep in mind its limitations. Estimates are imprecise. In order to obtain wood loads, it relies on making several assumptions about representative sampling, log travel times, and average log size. It is also limited to large pieces and has a limited range.

Acknowledgments

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Scour Morphology Downstream of Double-wing Log-Deflectors in Compare with Single-wing Log-Deflectors

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Abstract

Stream deflectors are in-stream grade-control structures presented as single-wing and double-wings Log-deflectors. The purpose of this study is to compare the scour morphology downstream of single-wing and double-wing Log-deflectors in straight horizontal channels. All the experiments have been carried out in a horizontal channel and in clear water conditions. Log-deflectors, with different heights and angles were tested. Different hydraulic conditions including densimetric Froude numbers, water head drops and tailwater values were studied. Based on the observed data, two types of scour morphology downstream of Log-deflectors have been defined.

Keywords: *Stream deflectors; Log-Deflectors; Hydraulic Structures; River Restoration; In-Stream Structures; garde-control Structures; Scour*

Introduction

Log-deflectors are grade-control structures presented in single-arm and double-arm form, which are partially placed in the streambed and usually are submerged even during low flows. Downstream of Log-deflectors, secondary flow develops scour pools. Log-deflectors divert base flows towards the center of the channel, creating scour pools and enhancing fish habitat. Backwater effects caused by channel constrictors facilitate gravel deposition upstream thereby improving spawning habitat for fish. In the scientific literature, there are no comprehensive studies on scour downstream of Log-deflectors structures.

Limited information is available on the scour downstream of in-stream structures. Bhuiyan et al. (2007) compared the maximum scour depth downstream of W-weirs with the previous study's results. Bhuiyan et al. (2010) investigated on bank-attached vanes for bank erosion control. Scurlock et al. (2012a, b) conducted experimental studies on different types of in-stream structures; Vane-Dike, Cross-Vane and W-weir. Pagliara and Kurdistani (2013) analyzed the scour geometry in straight rivers downstream of Cross-Vane. Pagliara et al. (2013, 2014a, b and 2015) investigated the scour morphology in straight rivers downstream of J-Hook vane, W-weir, Log-Vane and Log-Deflector structures respectively. Pagliara and Kurdistani (2014) compared scour hole characteristics downstream of Cross-Vane and W-weirs, highlighting similitudes and differences in the respective ranges of application. The main purpose of this study is to analyze the scour morphology downstream of Log-deflectors and highlight the differences and similitudes for single-wing and double-wing Log-Deflectors in horizontal straight channels.

Experimental Setup

A horizontal channel 0.8 m wide, 20 m long and 0.75 m deep located in the hydraulic laboratory of the University of Pisa was used to carry out the experiments. An overhead tank supplied the approaching stable flow. The flow discharge was measured using a calibrated tank with a precision of ±0.1 l/s. An ultrasonic distance meter with precision of 0.001 m has been used to read the water surface profile and the bathymetry of the mobile bed.

Results

Comparison of the experimental results shows that in the same hydraulic condition and deflector geometry, double-wing Log-Deflector makes a bigger scour hole and a dune that develops in whole the channel width. Fig. 1 and Fig. 2 show this phenomenon.

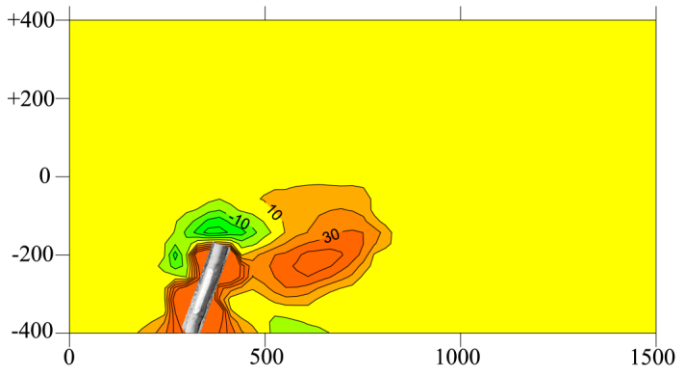

Figure 1: single-wing Log-Deflector with angle of installation 120°, F_d = 2.14, $\Delta y/h_{st}$ = 0.075, Morphology Type C (Numbers in the graph are in millimeters)

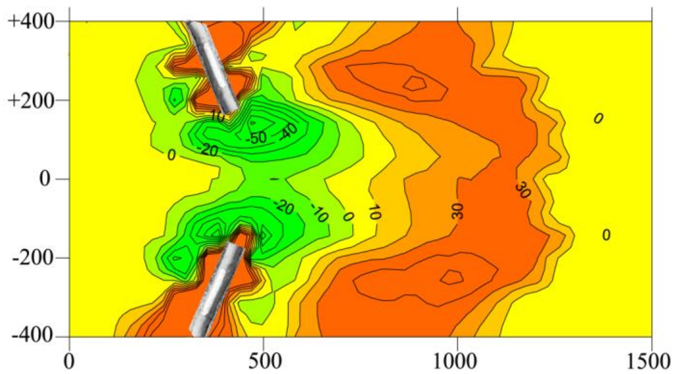

Figure 2: double-wing Log-Deflector with angle of installation 120°, F_d = 2.14, $\Delta y/h_{st}$ = 0.075, Morphology Type C (Numbers in the graph are in millimeters)

Conclusions

Single wing and double wings Log-deflectors were studied to investigate the scour morphology downstream of this type of In-stream structures. Scour typology included two types of scour. Type C where “the point of the maximum scour is developed at the end of the deflector towards the center of the channel” and Type D where “the point of the maximum scour is developed towards the channel bank”. The presence of double-wing Log-Deflector instead of single-wing Log-Deflector does not change the type of scour morphology but under effect of more flow contraction by double-wing Log-Deflector, bigger scour hole occurs and the dune develops in the entire channel width.

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Large wood monitoring in a river affected by a volcanic eruption in the South of Chile: How accurate are the data from satellite images?

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Abstract

Consideration of wood material can help explaining a series of in-channel morphological processes, so it will be of importance to know its variation and distribution in a fluvial system. This work tries to find how accurate is the measurement of the wood material from the interpretation of a satellite image (resolution 2.6 m), in a 0.6 km-long reach in the Blanco River (Southern Chile). This reach has experienced a strong input of wood material following an intense eruption of the Chaitén volcano. The interpretation of the satellite image is compared to data obtained through a field survey measuring individual wood pieces and jam dimensions in the same reach. As from the field survey data, results indicate that the interpretation of the satellite image understimates individual wood pieces by 40%; however, number of individual pieces forming jams were overstimated by 180% in the image, being this possible by an overstimation by 300% of the total area of the wood jams. Therefore this type of image is not suitable for a detailed analysis of the wood piece measurements in a river. Evidence is also the need to investigate the accuracy of the results using different resolution in remote images.

Keywords: *Large wood; Satellite image; Volcano eruption; Chile.*

Introduction

In-stream wood material is an important morphological agent to consider in forested catchments. The knowledge on the variation and distribution of wood material in river networks may help to explain a series of channel morphological processes (Montgomery & Piegay, 2003). The presence of wood increases the stability of the channel by reinforcing the banks, and in large rivers it can exert fundamental effects on channel planform and dynamics (Gurnell *et al*., 2002).

Beside, volcanic eruptions cause the more drastic changes in river systems. Channel morphology and processes of supply and transport of sediments and wood, and the dynamics of vegetation, among others, are severely modified by these catastrophic events (Pierson & Major, 2014). Lisle (1995) reports on the effects of wood material in rivers that were affected by the eruption of Mount Saint Helens in 1980; large volumes of wood along with ash and sediments from the slopes were supplied into the channels. Ulloa *et al.* (under revision) found a dramatic increase of wood material in the channel of the Rio Blanco, following the 2008 eruption of the Chaitén volcano, southern Chile.

Field surveys of wood material in large extensions of a river valley is highly time and cost demanding, generating low spatial detail and making it difficult to survey the same areas overtime (Marcus *et al*. 2002; Atha, 2014). However, recent technological advances provide, for example, easy access to satellite images that can help assessing the quantity of in-channel wood material (Marcus *et al*. 2002; Atha, 2014).

This study aims to compare the information on wood material volume and degree of aggregation obtained from satellite image analysis and from field survey, in order to understand more accurately wood contributions within the active channel of the Blanco River, which has been strongly affected by the eruption of the Chaitén volcano.

Study Area

The study area is a 0.6 km-long reach (4.9 ha) of the downstream course of the Blanco (or Chaiten) River, which is located about 254 km south of the city of Puerto Montt. The climate in the area is "west coast cool temperate climate with winter rainfall" exceeding 3,000 mm/year (Chilean Meteorological Office, www.meteochile.cl) and the forest cover is of an Evergreen Forest Type (Donoso, 1981). The 43% of the Blanco River catchment is covered by old-growth forests, 40% is shrub forest and 16% is covered by snow and glaciers. More information about the Blanco River and its basin can be found in Ulloa *et al*. (*in press*; 2015). The study reach is located within the Blanco River valley, some 6.5 km downstream from the Chaitén volcano and about 3.5 km upstream from the Chaitén town. This reach was affected by pyroclastic flows and sediments originated by the collapse of the volcanic dome during the explosive and effusive phases of the eruption (from May 2008 to March 2009), which generated up to 6-m thick layers of sediment. More information on these volcanic processes and their effects can be found in Major and Lara (2013).

Materials and Methods

The study reach is characterized by a high density of wood material, either individual (Large Wood, LW) or jam forming logs (Wood Jam; WJ) of different dimensions. Two methods for the measurement of wood material were compared. First, using ArcGis ® on a satellite image (2.6 m resolution) we visually registered LW as polyline and WJ as rectangular polygon. Second, the length and diameter of LW were surveyed in the field, and length and maximum width of every WJ were also measured to finally obtain WJ area. In addition, all the logs in every WJ were counted.

Results

Overall, fewer WJ with greater area are recorded through the images than from the field survey (Table 1). From field survey analysis, on average, each WJ contained 12.8 logs, with a minimum and maximum of 2 and 60 pieces per WJ, respectively. We found a linear positive relationship between WJ area and the number of logs in each WJ (Fig. 1). Using the equation resulting from Figure 1, 1802 logs were found in WJ, around 69% more than the field measurements (1064; Table 1).

With respect to the level of wood aggregation, using the traditional field method the 9% correspond to individual LW and 91% to logs in WJ, while from the image analysis just 3% corresponds to LW and 97% logs in WJ (Table 1).

Characteristics	Traditional method	Satellite image
Number of WJ	52	20
WJ area (m^2)	2756	7826
Mean WJ area (m^2)	53	391
Number of wood pieces in WJ	1064	1802
Number of LW	89	52
Mean LW length (m)	3.2	7.4
Range LW length (m)	1 - 18	3.2 - 16

Table 1. Comparison of results obtained through field survey and satellite image interpretation.

Discussions and Conclusions

The number of LW measured during the field survey was 40% higher than what was possible to identify from the satellite image (Fig. 2). This is probably due to the low resolution of the images, that allowed to detect only LW longer than 3.2 m, thus producing underestimation the number of logs (see table 1). Regarding the number of logs in WJ, results indicate that the estimation using the image gives a greater number (table 1; fig. 2), this is because the total area of jams is 180% higher than the one obtained in the field. Again, this is likely due to the resolution of the image, as for example it is difficult to separate neighbor WJ and the image interpretation will tend to group them into a single and larger WJ. Beside, in the field work it was possible to observe areas with small WJ located at close distance from others. Despite these differences, previous attempts (e.g. Atha, 2013) demostrate that the use of images is still an interesting alternative to field surveys for general observations of wood abundance and aggregation.

The results do not allow validating the use of remote image as a reliable method to obtain accurate data of abundance and aggregation of wood. Therefore, there is also the need to better explore the resolution of the images and the accuracy of data on woody material that can be obtained.

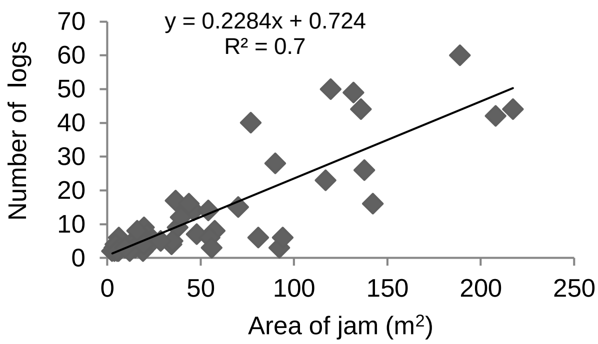

Figure 1. Relation between area of WJ and number of logs in each WJ.

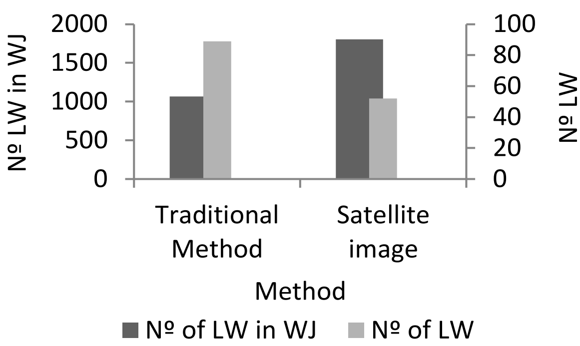

Figure 2. Comparison of number of LW and LW in WJ measured from field survey and interpretation of the satellite image.

Acknowledgments

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Modeling shallow landslides for LWD recruitment estimation

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Abstract

Shallow landslides play a key role in LWD recruitment providing a gross amount of woody material to streams, especially in headwater catchments. Most of deterministic stability models focusing on the correct identification of instabilities by calibration tend to overestimate the unstable areas prone to produce LWD.

In this work, we propose a new method based on the probabilistic approach of the limit equilibrium principle and on the distribution of soil reinforcement by roots that is related to forest stands characteristics. We compared the new method with the well-known SINMAP model. Results show that an event-based model like SINMAP provides a great overestimation of unstable area while the proposed model returns a better agreement with field evidences. Although some improvements are necessary, the new method seems to be very promising for a correct estimation of the LWD recruitment from shallow landslides.

Keywords: Root reinforcement, Infinite slope; Large Woody Debris; Forest Management.

Introduction

In low-order mountain streams, Large Woody Debris (LWD) recruitment is largely influenced by colluvial processes as landslides and debris flows which can provide a substantial quantity of wood (e.g. Keller & Swanson, 1979). In spite of that, the estimation of LWD volume from this source has received a relatively little attention (Miller & Burnett, 2007; Rigon et al., 2012). The deterministic models commonly used for slope stability seems to be not applicable for LWD recruitment estimation because they are calibrated on landslides occurred in the past and tend to overestimate unstable areas (Huang et al., 2006). In this work, basing on the advances in the field of soil reinforcement by roots, we developed a new method to obtain a map of unstable areas linked to forest stand characteristics, in order to estimate LWD recruitment from hillslopes. The method was applied to a small headwater catchment and the results were compared to those obtained by a deterministic stability model, the Stability Index Mapping software, SINMAP (https://github.com/eachiaradia/MW-SINMAP-v1.1-source-code/tree/master/MWSinmap).

Materials and Methods

As well known, the limit equilibrium theory provides the stability of a hillslope in terms of factor of safety, FS, which is affected by several degrees of uncertainty and variability (Hammond et al., 1992). SINMAP couples a spatially distributed hydrological model to the infinite slope equation and a calibration procedure based on historical events (Pack et al., 1998). SINMAP predicts the probability of stability, i.e. P(FS>1), basing on probability distributions of both hydrological (Transmissivity to Recharge ratio, T/R) and geotechnical (internal frictional angle, PHI, and soil-root dimensionless Cohesion, C) parameters, and adjusting their ranges by a calibration procedure in order to fit historical landslide positions (Fig. 1).

The new method, inspired to L1SA approach (Hammond et al., 1992), basically consists in a Monte Carlo procedure applied to each cell belonging to the catchment, where steepness and saturation are known. Some minor factors are set as constant (e.g. forest surcharge) whereas others are allowed to vary according to a uniform distribution (e.g. internal friction angle of soil) or according to empirical distribution (e.g. root reinforcement, Fig. 1). In particular, the novelty of the method stands in including the root reinforcement, c_r, obtained by the application of a root distribution model (Schwarz et al., 2012) calibrated on field collected data, and the Fiber Bundle Model (Pollen & Simon, 2005). In this way, the reinforcing effect of trees is strongly linked to the forest stand and a calibration on past sliding events is avoided. Both methods produced a probability of failure map. To evaluate the results in a quantitative manner, we used some performance indicators: Stable Rate SR = Sr/So; Unstable Rate UR = Ur/Uo; Modified Success Rate MSR = (1/2)*SR + (1/2)*UR (Huang & Kao, 2006) and Weighted Modified Success Rate, WMSR = (2/3)*SR + (1/3)*UR (Bischetti & Chiaradia, 2010), where: Sr is the number of rightly predicted stable cells, So is the total number of observed stable cells, Ur is the number of rightly predicted unstable cells, Uo is the observed unstable cells (i.e. historical landslides). To account for the probability of failure returned by both the models, Ur was obtained as sum of P(FS<1) for all the cells where an historical event happened, and Sr was obtained as sum of P(FS>1) for all the cells where stable conditions were observed. In this way, if the model predicted 99% of instability for a cell, a weight of 0.99 was assigned to that cell.

The two models were applied to a small headwater catchment, a third order segment of the Brembo River (45.99655, 9.58620). The area is characterized by high precipitation (about 1400 mm), cold temperature (mean annual temperature about 7°C); soils are umbrisol with a low permeable silty matrix over a semi-permeable siliceous substrate. Forests are coniferous, mainly Norway spruce and silver fir.

Results

By calibrating SINMAP, T/R ranged between 500 and 1500, PHI between 29 and 35 and C between 0 and 0.4. The maximum C value corresponds to a soil-root cohesion, c_r, of 3.4 kPa, considering an average depth of 1 m and a forested soil density of 1000 kg/m^3 (De Vos et al., 2005). The instability map showed that 6% of the total analyzed area is stable, 39% shows lower probability of instability (less than 50%) while the 55% shows the highest probability of instability. In the case of the new model, c_r ranged between 0 and 66 kPa and the instability map showed that only 4% of the area is completely stable while the 91% has a lower degree of instability (less than 50%); only 5% of the area has high probability to manifest instability phenomena.

In terms of performance indexes, the two models showed great differences. In the case of SINMAP, UR has a better result than SR (65% and 44% respectively) while the new model had a high value of SR (95%) and a low value of UR (4%). Combining the two terms in the MSR returns a better index in case of the SINMAP model (0.55 vs 0.5), while the contrary for WMSR (0.65 for the new model and 0.51 for SINMAP).

Discussions and Conclusions

The probability distribution of failure is different for the two models. In the case of SINMAP, more than half of the area is classified as high probability of failure, and this is a consequence of calibration, which forces towards very severe conditions inducing widespread instability to obtain a higher UR index. On the other hand, SINMAP underestimated the stable area. On the contrary, the new model has proven to better reproduce areas of low probability of failure, as showed by high values of SR. Considering the combined indexes, in the case of MSR, which equally subdivides the weight of the two original indexes, results are similar, whereas in the case of WMSR, the new model seems better with a SR value higher than SINMAP. Finally, besides numerical indexes, it is quite evident that the stability map obtained by the new method gives a more realistic picture of the general stability of the watershed (i.e. forest land are mainly stable).

As a future perspective, the new model could include in LWD estimation also the effect of both natural and anthropic factors of forest alterations (e.g. diseases, fire or clearing).

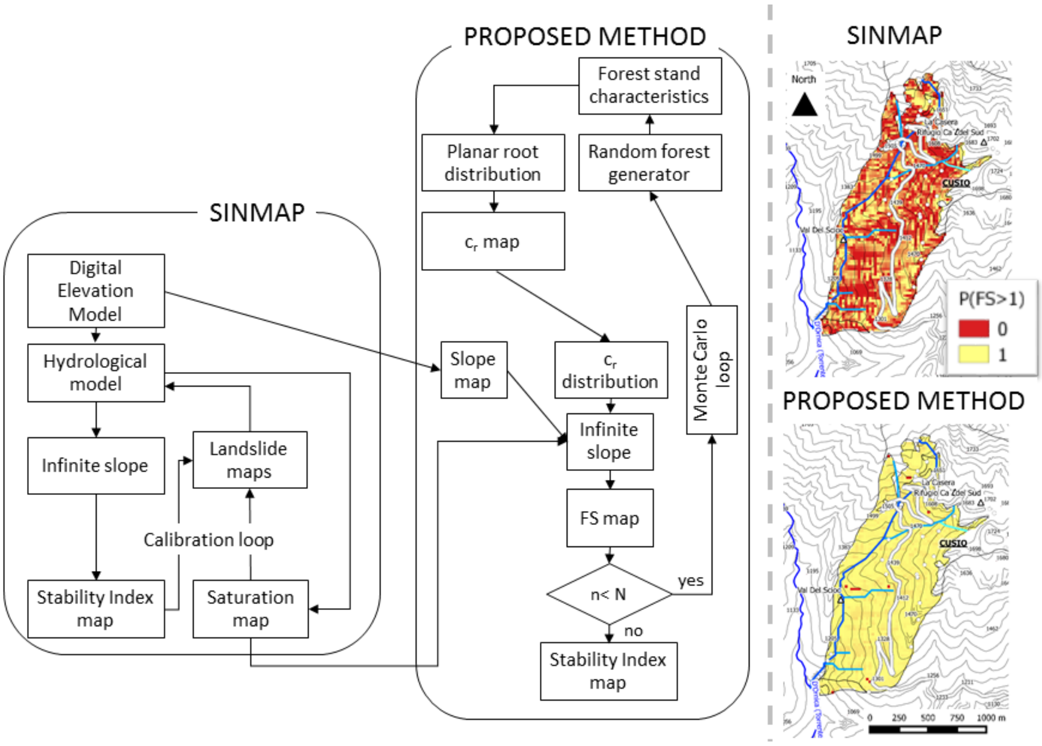

Figure 1: left: model application procedure; right: maps of probability of stability, P(FS>1), from SINMAP (above) and new model (below).

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Improvement and validation of video monitoring for floating wood under flood and wind condition in Ain river

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Abstact

The transport of wood in rivers during floods is an important process that underlies differences in channel habitat and morphology between water courses and regions. It is necessary to contribute quantitative data which decently address management objectives and calibrate wood budgets. In this study we use a streamside video camera to detect wood discharge in the Ain River, France. And then, a semi-automatic logging and annotation algorithm was coded in OpenCV to help export information from the videos. Verification of the procedure includes tests of detection frequency, wood velocity, and piece size, to describe the relation between the fluxes of floating wood within flooding and wind condition. A log base two transformation is proposed to classify wood by piece length. It was found that a wood transport threshold occurs at approximately two thirds of the bankfull discharge. Wood transport follows a positive linear relation with discharge up to the bankfull discharge but is both more variable and less sensitive to discharge when the floodplain is inundated. Transport rates are approximately four times higher on the rising limb of the hydrograph than on the falling limb. Wood transport estimates from a three-stage rating curve are two to 10 times higher than those from a wood budget using local and aerial surveys of upstream dynamics. During wind condition, it was found that less wood was detected by monitor.

Keywords: *river; wood budget; wood discharge; video camera.*

Hydrogeomorphic Characterization of Forested Fans at Lake Baikal, Siberia

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Abstract

We here performed an integrated analysis using remote-sensing data to characterize morphometries and vegetation characteristics for the population of fans at Lake Baikal, Siberia. Our analyses suggest that morphometric relationships between depositional features and riparian vegetation exist on the level of spatial and temporal scales. Fan deltas form a product of sedimentary erosion and deposition and are influenced by local environmental conditions (Fryirs and Brierley, 2013), and they usually show vegetation covers of different maturity levels. In this work we conducted a comprehensive study of fan deltas at Lake Baikal and investigated 33 features in great detail. In order to understand the interrelationship with hydrodynamic settings we investigated morphometric and environmental parameters that might control or influence formation of fan deltas. Final aim of our study was to establish a connection between different geomorphic parameters of fan deltas and observed vegetation in order to pin down prevailing hydrodynamic conditions that contribute to the genesis of fans. By using remotely-sensed satellite imagery and digital elevation models, quantitative morphologic characteristics and vegetation covers could be derived from spatial analysis. A typology-based classification of fans derived from geomorphological features as suggested in previous work by Stanistreet & McCarthy (1993) as well as Blair & McPherson (1994) was complemented by vegetation studies. Our results show that fans can be classified according to their hydrodynamic conditions, each with distinct sedimentological conditions and vegetation characteristics.

Keywords: *Fan deltas; Lake Baikal; Riparian forest; Geomorphology*

Introduction

Fan deltas are coastal alluvial fans that prograde into an aquatic body, such as a lake or the sea. Morphology and shape of such fans are a product of fluvial deposition and environmental conditions which are both subject to various controlling factors (Holmes, 1965). While fan deltas are of some economic interest as they are potential hydrocarbon reservoirs and provide favorable conditions for human settling and agriculture the characterization of (native) vegetation on fans has received only limited attention in recent literature. It is our aim to understand and to quantify the interrelation between water flow, sediment dynamics and vegetation and the geomorphological response of fan deltas as it has been suggested by Giles (2010) that in particular morphometric factors and their complex interplay can be used to extrapolate fan-delta characteristics and assess the role of mature vegetation in fan-delta genesis. Riparian vegetation is considered to significantly influence the geomorphology of fluvial systems, affecting channel geometry and flow dynamics. In particular forests have physical and biological functions, as they are important for balancing nutrient input and significantly influence hydraulic structures (Wilford, et al. 2005b).

In order to examine the effects of vegetation on channel form, flow dynamics and morphological trends during fan evolution, remotely-sensed satellite imagery and digital elevation models were analyzed in a systematic survey.

Study Area

We selected Lake Baikal, Russia, as a study area because of its rich variety of morphologic settings, location and varied shore physiography as expressed by different fan delta types. Lake Baikal is the biggest, oldest, and deepest lake in the world covering an area of 31,500 km^2. With its catchment area of 55,700 km^2, it carries around a fifth of the world's freshwater supplies. Lake surroundings are characterized by a continental, relatively mild coniferous forest climate (Scholz and Hutchinson, 2000) and it's surrounded by large mountain ranges.

Lake Baikal is situated in the northwest of the Baikal Mountains, in the north-east the Bargusin mountains and the southwestern part of the Primorsky Range. In the southeast the Khamar-Daban mountain range is located which causes separation of the lake from Siberia's prevailing climatic conditions (Wein, 1999). Climate conditions and a low population density ensure that most fans are relatively pristine and therefore well suited for our study. Different hydrodynamic conditions under which fan deltas have evolved are reflected in geomorphic form and vegetation cover of individual fans.

Data and Methods

For this study we employed remote-sensing data in order to characterize hydrodynamic parameters and vegetation texture for fan deltas and morphological characteristics.

For mapping of different alluvial fan bodies freely available digital datasets of the Landsat Enhanced Thematic Mapper (ETM+) (NASA Landsat Program, 2003) with a geometric resolution of 15-30 m/px were utilized. Vegetation was classified into different international vegetation classes after Schroeder (1998).The main focus of these investigations was to identify the vegetation textures and to relate it with hydrodynamic parameters. For the detection of morphometric parameters as input data for subsequent hydrological studies digital terrain model data of the Shuttle Radar Topography Mission (SRTM) (Shuttle Radar Topography Mission, 2004) and the ASTER GDEM with a scale of 3 arcsec and 1 arcsec, respectively, were used. Using these datasets we determined different morphological characteristics, such as sizes of drainage basins, transport areas and areas of deposition derived from spatial semi-automatic analysis. Determinations of boundaries of drainage basins and networks complemented these analyse which were carried out in a geographic information system (GIS). Flow direction and flow accumulation were calculated in order to delineate the drainage basins. Channels were derived from flow accumulation data and were matches with channels that could be identified in satellite imagery of the same area.

Results and Discussion

Preliminary results indicate a correlation between vegetation classes and fan morphology and maturity as well as flow conditions at the fan surface. By plotting typical hydrodynamic factors, such as catchment sizes, the morphometry of associated rivers and slope angles as well as sizes of fan deltas, individual typologies could be characterized. This allows us to draw conclusions on the hydrodynamic conditions at formation time. Our analyses generally confirm that there is a positive correlation between e.g., fan areas and sizes of catchment areas as well as between fan areas and lengths of valley lines of associated rivers. Additionally, our analyses show a negative correlation between average fan slopes and sizes of catchment areas. Furthermore it was possible to identify a connection between vegetation classes and the associated hydrodynamic conditions as derived from fan-morphological classifications. This, for example, is expressed in vegetation classes associated with debris-flow conditions and fluvial fan-delta systems.

Our observations are generally in good agreement with previous dispersed analyses from other areas (e.g. Wilford, et al. 2005a). The study was conducted in an area with variable geomorphological and seasonal climatic conditions.The applied methodology proved to be adequate to be compared to field investigations as confirmed by our results. It could be demonstrated that assumptions for hydrodynamic processes based on the use of basis geomorphic parameters of fans and their watersheds attributes can be considered adequate. Additionally, a separation and analysis of different typologies provided much more distinct distribution characteristics and better correlations between different fan morphologies which allow constraining boundary conditions, like hydrodynamic conditions, and their potential influence on shape in a much more efficient way. However, local or experimental studies (e.g. Clarke, 2010) studies need to be incorporated in our analysis in order to prove the conceptual layout. First analysis using an integrated vegetation analysis shows to be feasible and conducive to extend our model approach as there are strong correlations between vegetation characteristics and fan morphologies.

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Instantaneous movement of logs in two different impacted gravel-bed rivers

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Abstract

Wood exerts a fundamental role in river systems, providing habitats for fishes and invertebrates, and enhancing the dynamics of geomorphic processes. However, several studies have observed that transported wood could be a source of hazard in sensitive structures. For this reason, the interest to analyze the dynamics of wood in-channel is recently increased. The study has been carried out in two Italian gravel-bed rivers, which have suffered of different human pressures. Log mobility and velocity during floods have been measured by using GPS tracker devices, which provided to an instantaneous GPS position of logs during the movement. A preliminary analysis of the GPS trackers data show a different trend of log velocity between the two rivers , with a higher mean velocity of in transport logs in Piave River and a displacement length of logs quite irregular with temporary stops on the braided Tagliamento River. The study have been conducted in order to improves the ability to understand in transport wood processes, in particular the log displacement length and velocity during floods in different environmental systems. Information that could allow to define a better river management strategies.

Keywords: *Tracking systems; Wood dynamics; Log velocity; Piave & Tagliamento Rivers, Gravel-bed rivers*

Introduction

Wood in river systems exert a fundamental geomorphological and ecological function (Piégay, 2003; Gurnell, 2013). Because of that, and due to the potential hazard on sensitive structures represented by wood transported during floods (Ruiz-Villanueva et al., 2014), considerable efforts have been recently devoted to assess in-channel wood budget (Benda and Sias, 2003; Marcus et al., 2011; Schenk et al., 2013), analyzing the balance of wood input and output at various time scales. The first budget exercise was carried out by Keller and Swanson (1979). More recently, Marcus et al. (2011) calculated an annual wood budget using a relation between wood transport rate and discharge. However, there is still a considerable lack of knowledge on the entrainment, transport and deposition processes of large wood, especially in large and complex gravel-bed rivers (Welber et al., 2013). Few field observations confirmed that smaller and isolated logs are more mobile than wood pieces longer than the bankfull width (Gurnell, 2013). Also, evidence shown that more logs are entrained and transported during the rising limb of hydrographs (MacVicar and Piégay, 2012; Schenk et al., 2013; Ravazzolo et al., 2015), but field observations are still scarce.

The aim of this study is to investigate log velocity during flood events in two gravel-bed rivers (Piave and Tagliamento rivers, Italy) which differ for the degree of human pressures at which they are subject (higher in the former than in the latter).

Study Area

The research has been carried out in two gravel-bed rivers located in North-east of Italy (Piave and Tagliamento rivers, respectively). The two rivers are comparable in terms of basin size, geological settings, and vegetation species, but differ in terms of the level of human pressures at both the basin and reach scales. A wide range of intense human impacts have influenced the Piave River (i.e. major dams building, gravel mining, and bank protections), on which the surveys have been carried out in a reach called Quagliodromo (2.2 km long and 370 m wide), which has a braided /wandering morphology. Because of the reduced human impacts relative to other rivers in the region, the Tagliamento is considered one of the few European gravel-bed rivers with high eco-morphological complexity and dynamic (Tockner et al., 2003). Here the field surveys have been carried out in the Cornino site, which is around 3 km long and 800 m wide, and can be described as a large bar-braided reach.

Materials and Methods

Overall, 15 active and 42 passive GPS tracker devices were installed in logs of different size in the Piave and Tagliamento rivers, respectively. The active GPS trackers (Trim Trac Locator purchased from Trimble Company) used in Piave River have dimensions of 143 x 76 x 38 mm. On the other hand, the passive GPS trackers (3100-EXT purchased from LandAirSea Company) used in Tagliamento River has dimension of 80 x 100 x 40 mm. The active devices differ from the passive for the capacity to send, in real time, Short Message Service (SMS) over GSM communications network (i.e. time, position, batteries lifetime). Both active and passive devices allow to obtain the instantaneous GPS position which allows to analyze displacement length and velocity of moving logs. The devices were waterproofed with plastic boxes and then fixed to trunks using a steel chain. Differential Global Positioning system (DGPS) of each logs was survey before and after every flood event.

Results

Five and one tagged logs were transported in Tagliamento and Piave River, respectively, over the length of the study period (from April to November 2013 for Piave River and from June 2010 to October 2011 for Tagliamento River). The mean travel distance and velocity recorded in Piave were 2.5 km and 2.3 m s^{-1}. On the other hand, 13 km and 1.8 m s^{-1} were the mean travel distance and velocity of the logs in the Tagliamento. Figure 1 shows that the mean velocity of the tagged log with GPS_P1 in Piave River (tree with 10.5 m long, 3 m wide considering the branches, and diameter of 0.17 m) was the same than a smaller transported log with GPS_T3 in Tagliamento River (trunk with 1 m-long and a diameter of 0.15 m). Overall, in Tagliamento River the transported logs collected a lower and irregular trend of mean velocity than the transported log in Piave River. It is worth noticing that in both the Piave and Tagliamento rivers, the log velocity was higher shortly after the entrainment threshold and decrease during the transport.

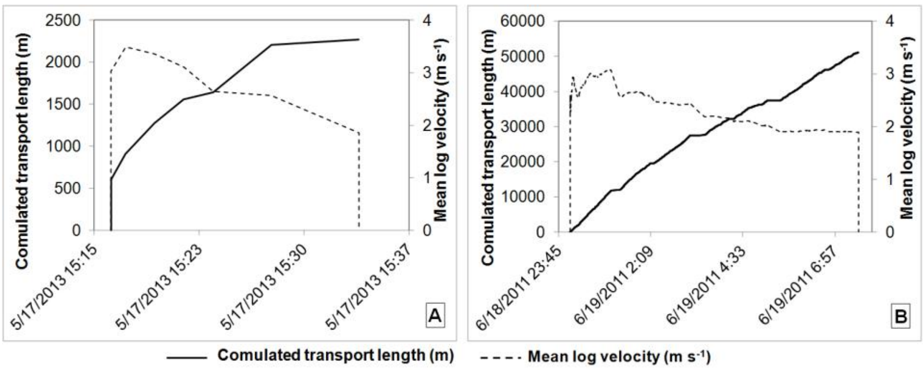

Figure 1. Cumulated transported distance and mean velocity of log with GPS_P1 (A) and GPS_T3 (B) of Piave and Tagliamento River, respectively.

Discussions and Conclusions

Because the explored floods are very comparable in terms of peak discharge (~60% of bankfull stage) and duration (~150 h), the different mobility characteristics of logs are likely due to the different morphological pattern of the Piave and Tagliamento rivers. The high natural dynamicity of Tagliamento River and the frequent shifts of the main channel during flood events, are probably related to the fact that logs tend to be transported above the bars with high probably to temporally stops on bars or pioneer islands, decreasing the mean velocity. On the other hand, in wandering rivers (i.e. the Piave River), the logs tend to follow the main channel, probably along the thalweg, with less chances of being trapped or stranded on gravel bars, resulting in higher mean travel velocity of logs if compared with what observed in the braided river. Future challenges will be to investigate the real causes of the temporal stops during transport (i.e. using video cameras) and improve the morphological changes of the river bed due to the flood events (i.e. carrying out LiDAR surveys pre and post flood event).

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In-channel LW modelling in the Cordevole basin, Italy.

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Abstract

Wood in rivers provide many benefits to the fluvial systems, including ecological and morphological aspects. Nevertheless, the hazards that may result from its presence are to consider. In Italy, a significant reduction of the dangers associated to this phenomenon is achieved thanks to the riparian vegetation cutting measures. The assessment of transported Large Wood (LW) is essential for achieving a good management of riparian system. In this work, a wood budget method was applied in order to model the LW input, as well as its transfer along the fluvial network. Three sub models form this model, which uses GIS-metadata. Submodel 1 calculates instability with the help of the landslides and debris flows susceptibility maps and forest maps. The submodels 2 and 3 calculate hillslope transfer and river transfer, respectively. The model predicts volume and distribution of in-channel LW in three different scenarios for the main tributaries of the Cordevole river basin (843 km^2), in Belluno Province, northeastern Italy. The obtained results may permit to design and to adopt measures and strategies for an integrating in-channel wood and riparian vegetation management. Furthermore, this model can be helpful in the framework of river's hydromorphological quality maintenance required by the EU Water Framework Directive.

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Keywords: *Large wood recruitment; in-channel wood volume prediction; Cordevole river, Italy;*

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Introduction

Both ecology (Jackson and Sturm, 2002) and morphology of a fluvial system may benefit from multiple positive aspects that the presence of wood provides. On the other hand, the different threats that may result from the transport of wooden material during floods are to consider (Mazzorana et al., 2011). In this sense, the presence of such material may increase the vulnerability of the territory, especially in the case of extreme floods (Rickenmann, 1997; Comiti et al., 2008). In Italy, an important reduction of the hazard associated to this phenomenon is achieved thanks to the riparian vegetation cutting measures. In this context, the development of precise prescriptions about the management of the riparian woods are required. At the same time, these prescriptions concern also the artificial intervention design (selective check dam). For this purpose, the assessment of the transportable wood volume during a flood is essential. Few studies about wood mobility in Italy have been developed (e.g. Bertoldi et al., 2014; Ravazzolo et al., 2015). In this work, a wood budget approach was applied in a mountain basin, taking into account the hydromorphological conditions derived from Digital Terrain Model (stream power, width and depth relative to log size) that characterize the stream analyzed. We assume that the Large Wood (LW) input supplied from unstable forests results mainly from landslides and debris flows (e.g. Comiti, 2013). Moreover, the use of the DTM permit to assess the LW transfer along the hydrographic network. This extended abstract shows the results obtained in the Cordevole basin (drainage area = 843 km^2), where a conceptual GIS-based model (Rigon et al., 2012) for predicting the location of recruitment sites, LW transport and depositional reaches has been applied.

Study Area

The Cordevole River is located in the Province of Belluno, Veneto Region (northeastern Italy) (Figure 1) and is ≈ 79 km long. It is the main tributary of the Piave River. The basin area (843 km²) is characterized by mountainous terrain that generates a hydrographic network (1440 km, drainage ratio = 1.7 m^{-1}) with a complex morphology, also due to the geology of lower slopes formed by erodible sedimentary rocks and quaternary deposits. Main rivers are shown in Figure 1. Climate is characterized by annual average temperature is ≈5°C while annual precipitation is ≈1100 mm. Woodlands are mainly composed of spruce and cover approximately 40% of the basin. Human intervention led the construction of artificial infrastructures in the stream (e.g. check-dams, transversal structures, bank protections), often located near villages and roads. For more information about the study area see Rigon et al. 2012.

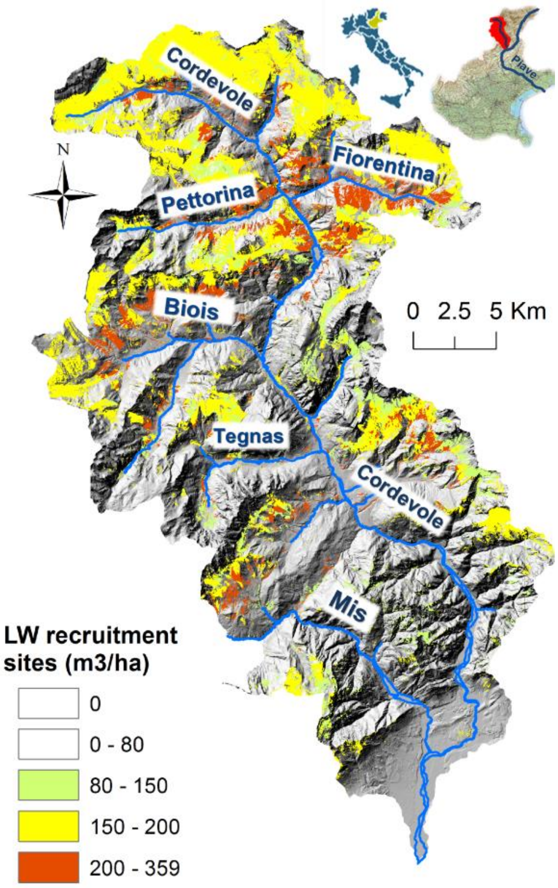

Figure 1: Cordevole basin and river network. Blue lines identify the active channel. LW recruitment sites (m^3/ha), derived from conceptual GIS-based model, are highlighted in different color.

Material and Methods

The basic database consists of GIS-metadata available on the national (http://www.pcn.minambiente.it/GN/) or regional (http://www.regione.veneto.it/web/ambiente-e-territorio/geoportale) geoportals. The main processed information (ESRI® Arcmap) are: 2012 orthophoto, digital terrain model (DTM), geolithological map, CORINE land cover and Inventory of landslides in Italy (IFFI Project). The conceptual GIS-based model (Rigon et al., 2012) was applied using a 5-m resolution cellsize, and is formed by three sub-models. i) Instability sub-model calculates the LW recruitment sites and volume (LWR map) by an intersection between Landslides and debris flow susceptibility maps (LDF map) and forest map (F map). LDF map was obtained through a geostatistical bivariate analysis (''WofE,'' weight of evidence method, Bonham-Carter et al., 1989, implemented in Spatial Data Modeller application package), based on a comparison between the density of landslides (IFFI Project) and several potential factors. F map contains the volume of wood per hectare and is derived from an interpolation of map with forest stand mass and CORINE land cover. ii) Hillslope transfer sub-model simulates the displacement of unstable LW volume toward the channel network by using the ''slope decay'' function, which depends by local morphology and by the distance along the drainage line (implemented in ''TauDEM' Gis tool'). iii) River transfer sub model reproduces in-channel LW transferred downstream through an algorithm that calculates the possibility of flotation according to the unit stream power (using the formula specified in Rigon et al., 2012), the presence of critical section and the relative size of LW/channel. An essential point consists in the mapping (photo interpretation) of all critical sections that determine the "capture" of LW displacement, and estimate a locking percentage for every artificial intervention. In some areas are available an artificial intervention inventory, to be checked.

Results and Conclusions

The volume and distribution of in-channel LW along the river network is calculated by the model for three different levels of estimated likelihood of occurrence: high, scenario 1; medium, scenario 2; and low, scenario

3. These different scenarios were chosen based on susceptibility (LDF map) values, i.e., 0.5–1, 0.25–0.5, and 0.05–0.25, respectively. Model calibration was made using the results of scenario 3 and the real quantity of LW in 13 sub-basins of the High Cordevole (Rigon et al., 2012). Figure 2 reports an example of final raster obtained through the application of the conceptual model as scenario 1 regards. The Table 1 summarizes the possible LW volumes mobilized during flood events for the main tributaries of Cordevole river. These volumes, although might be affected by possible bias, may give useful indications about the riparian vegetation management, In this sense, such results allow to identify the best design solutions and decide the artificial interventions about the risk management, in particular about the hazard related to in-channel wood, as already done in the Rienza river at Brunico (Comiti et al., 2012). Thanks to this model, it is possible to assess material that should remain in the channel as wood storage, as well as the mature vegetation in the riparian areas, which are fundamental factors for the hydromorphological quality (EU Water Framework Directive). Once the implementation of the model will be completed, especially through the definition of critical sections and with the improvement of transfer along the water network (river transfer sub model), we plan to extend the modelling to the entire mountain hydrographic network of the Veneto Region. Finally, the obtained data can be made available in a web-GIS, for a possible use by river management institutions.

In-channel LW volume predicted

Basin	Scenario 1		Scenario 2		Scenario 3	
	(m^3)	(m^3/ha)	(m^3)	(m^3/ha)	(m^3)	(m^3/ha)
Cordevole 1	98813	1986	3663	74	472	9
Cordevole 2	61996	81	845	1	385	1
Fiorentina	116704	4027	11590	400	764	26
Pettorina	34556	2051	563	33	230	14
Biois	77593	1356	1124	20	702	12
Tegnas	17130	193	621	7	260	3
Mis	3390	18	1828	10	1235	7

Table 1: Conceptual GIS-based model Calculation of in-channel volume (total and in relation to active channel area. Cordevole1: drainage area upstream Pettorina and Fiorentina confluence. Cordevole2: basin area downstream at the outlet (Piave confluence.)

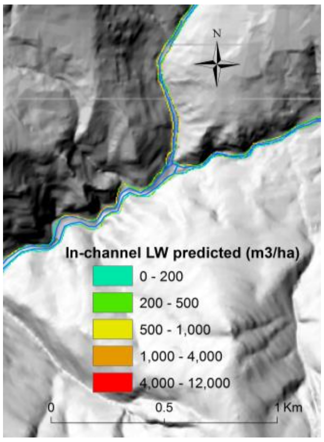

Figure 2: example of final raster obtained through the model.

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Assessing large wood and wood-jams volumes by TLS surveys

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Abstract

Wood in rivers can affect the hydrological regime, sediment transport and the ecological status of the water course. On the other hand, it may also increase the risk of flooding and clogging the runoff sections. The importance to know the amount of wood in rivers, has encouraged the employment of new technologies in order to obtain information on wood material faster and more precisely than through the traditional method based on manually field surveys. An alternative method to define the volume of large wood (LW) and wood jams (WJ) is proposed in this research, using the Terrestrial Laser Scanner (TLS) and the derived high-resolution Digital Elevation Model (DEM). The study was carried out along an area of about 7 ha of the gravel-bed Piave river (North-East of Italy). Wood volumes extracted from the DEM is compared to those obtained from the field activities. Results shows the potentiality of this device to provide accurate values. The volume of WJ, derived from the DEM, is slightly overestimated than the result obtained from the traditional methodology (+5.6%, corresponding to +15.7 m^3 ha^{-1}). The calculation of LW volume appears more uncertain, showing a consistent underestimation (-80.7% corresponding to -67.41 m^3 ha^{-1}). This is probably due by the difficulty to detect in detail the smaller logs by the TLS device. However, the integration of DEM with other data provided by specific techniques, able to analyse more in detail the LW dimensions, might allow the improvement of such methodology.

Keywords: Large wood, wood volume, Terrestrial Laser Scanner, Digital Elevation Model, Piave river.

Introduction

Wood material delivered into, transported or stored in a river can influence its geomorphology and ecology (Seo *et al*., 2010). Individual large wood (LW) and wood jams (WJ), formed by more than two single elements, can affect the structural complexity of the systems altering flow hydraulics, controlling both storage and transport of sediments (Keller & Swanson, 1979), and promoting the processes of pools and fluvial islands formation (Gurnell *et al*., 2005). However, wood can represents an additional source of risk during high magnitude events, damaging the human structures (Diehl, 1997). Therefore, to ensure the maintenance of natural fluvial ecosystems as well as to mitigate damages related to wood appear essential to analyse both the distribution and the abundance of wood in a river, thus permitting to define correct management approaches. Traditional methods to quantify the wood volume are commonly based on manual surveys, this methodology is simple to execute and provide very accurate data but, on the other hand, it is very time-consuming. In the last decade new technologies have been introduced, for example remote images (Atha, 2013) or LiDAR data (Bertoldi *et al*., 2013). The study aims to analyse the capacity of a Terrestrial Laser Scanner (TLS) to assess the wood volume in a fluvial system through a comparison between data provided by manual field surveys and those obtained by TLS-derived Digital Elevation Model (DEM).

Study Area

The study area extent for 7.54 ha into the middle course of the gravel bed Piave River (North East of Italy). It flows south for about 220 km from the Dolomite region to Adriatic Sea and the drainage basin covers an area equal to 3899 km^2. In the middle course the hydrological regime features average annual precipitation equal to 1350 mm, with the main floods occurring, typically, in summer and autumn. Fluvial morphology of the study area is characterized by braided channel patterns, with median grain size of 20-50 mm and average channel slope of about 0.4% (Comiti *et al*., 2011).

Materials and Methods

Field measurements were carried out to obtain the main wood dimensions for both LW (diameter and length) and WJ (length, width and height), respectively, using the threshold of 0.10 m for the diameter and 1 m for the length (Jackson & Sturm, 2002) Simultaneously, from TLS survey was obtained an average point density equal to 2000 point/m^2. More information about the TLS and geomorphic approach applied can be found in Picco *et al*. (2013) and Tonon *et al*. (2014). TLS data were processed using Cyclone 7® software in order to register and georeference the individual point clouds while ArcGis 10® was employed to create a high-resolution DEM (0.08 m cell size). The detectable woody elements in DEM were identified, by eye, and registered as polygons (Fig. 1). The area and height of each polygon were extracted using Zonal Statistics allowing to calculate the wood volume. A comparison between the wood volume measured in the field and the wood volume derived from DEM was carried out. Moreover, two polynomial regression models were constructed, to estimate wood volume for LW and WJ, separately. Large wood and WJ area and height were introduced in the regression model as independent variables.

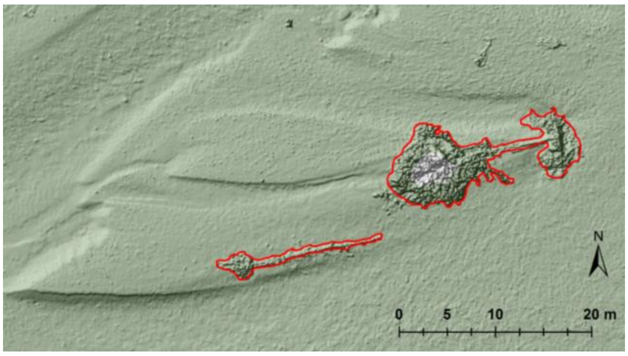

Figure 1: digitalization of LW on the high-resolution DEM (0.08 m cell size)

Results

Overall, 98 LW and 45 WJ were detected in the field. Whereas there was a decrease of 46.2% and 55.1% in the number of LW and WJ, respectively (Table1). With respect to the volume computation, the best agreement between the traditional volume and the value derived from the DEM has been found for the WJ, with a slight overestimation of about 15.7 m^3 ha^{-1} that corresponds of an estimation error of +5.6%. Regarding the LW, the volume obtained from the DEM is 80.77% lower than the traditional volume, corresponding to an underestimation of about 67.4 m^3 ha^{-1}. Regression analysis provided two significant models (p-value<<0.05) to predict the wood volume from the TLS-derived DEM. The R^2_{adj} obtained for the LW and WJ volume were 0.96 and 0.90, respectively.

	Traditional method	TLS-derived DEM	Δ	Error %
Number of LW	98.0	67.0	-31.0	- 46.2
Number of WJ	45.0	29.0	-16.0	- 55.1
Total LW volume (m^3 ha^{-1})	150.8	83.4	-67.4	- 80.7
Total WJ volume (m^3 ha^{-1})	147.7	156.5	+15.7	+ 5.6

Table 1: Comparison of results obtained from traditional field activities and TLS-derived DEM

Discussions and Conclusions

Despite the resolution of DEM (0.08 m) the number of LW and WJ identified in the DEM is lower with respect to those measured in the field. This divergence is probably due to the position of the elements, in fact the majority of the LW and WJ not identified were located along the riverbanks or on the border of wetted area where shadows and water do not permit to achieve an homogeneous point density from TLS. Overall, the results obtained from the high-resolution DEM have demonstrated the capacity of TLS to correctly provide wood volume information, notably for WJ. The high underestimation concerning the LW is probably related to the smallest dimensions of single logs. However, using the regression models we plotted the predicted wood volume with the traditional volume (Fig.2), obtaining a higher prediction accuracy for WJ (R^2_{adj} 0.91) than the LW (R^2_{adj} 0.64). Results shown in this study demonstrate the possibility to achieve wood volume information using the TLS, with high accuracy data especially concerning WJ. LW appear to be more difficult to analyse but the integration with other specific technique (see Tonon *et al*., 2014) in the data processing could improve the reliability of this technique.

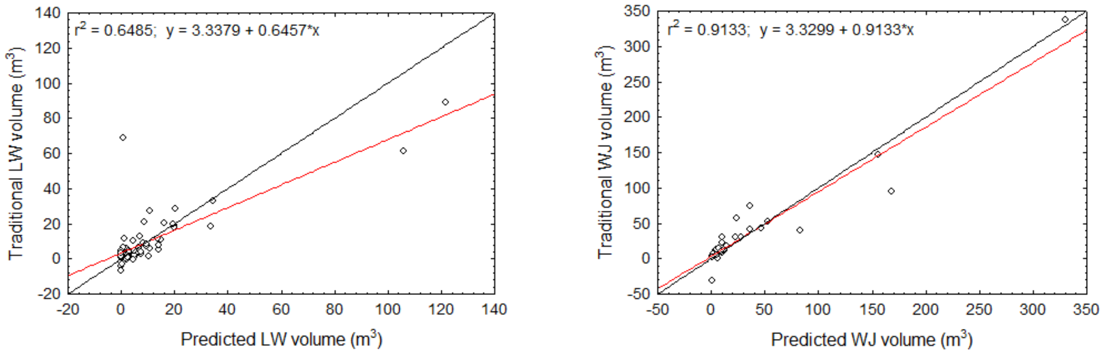

Figure 2: plots of predicted versus traditional volume for individual large wood (left) and wood jams (right)

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Methodological approach for assessing the Large Wood budget in large gravel bed rivers (preliminary results)

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Abstract

Positive and negative effects of Large Wood (LW) in rivers could be managed through the development of a mass budget analyzing the input and output factors. In fact, LW budget may be important to define the main processes of LW recruitment as well as to assess its persistence and mobility. A quantitative short-term LW budget, as a result of a significant flood (Recurrence Interval ≈ 6 years), is performed in this research. The study was carried out in a 1 km-long reach located in a large gravel-bed river in the North East of Italy (Piave River). The recruitment of LW by bank erosion as well as fluvial transport of LW into and out of the study area were analyzed. The preliminary results of the data collected shows that almost all LW previously stored in the study area was mobilized by the flood, the 82.15% has been transported outside of the study area, the 17.73% has been involved in the internal displacement whereas only two elements remained in the original location. After the flood, 99.83% of LW has been transported into the study area from upstream, whereas the input by bank erosion may be neglected. Overall, the equation of LW budget applied reveals a variation in the amount of LW stored equal to + 157.32% (67.17 m^3 km^{-1}). The aim of this study is to increase the knowledge on the LW dynamics in order to complete comprehensive LW budget for large and wide fluvial systems.

Keywords: Large Wood budget, LW transport, bank erosion, gravel-bed river, Piave River

Introduction

Large Wood (LW) in a fluvial system can be presents as both individual pieces and accumulations called jams (Abbe & Montgomery, 1996). It interacts with a wide range of fluvial processes thus affecting the structural complexity of the river (Keller & Swanson, 1979) as well as increasing the hazard in sensitive places such as bridge during floods (Kothyari & Ranga Raju, 2001). As a result, the scientific community has focused in the study of LW in order to quantify the wood dynamics in the mass balance context (Keller & Swanson, 1979). Given a spatial and temporal scale, Martin & Benda (2001) proposed a quantitative framework to analyze the budget of LW as result of the differences between input and output factors. The inputs are represented by the lateral recruitment and fluvial transport of LW into the reach under consideration, while the outputs are represented by LW transported out of the segment and the loss of LW by overbank deposition and degradation. Most of LW budgets available in literature were completed for mountain streams at various time and spatial scales (e.g. Benda & Bigelow, 2014). More recently, studies on LW budget were developed on larger rivers (e.g. Schenk *et al*., 2014). However, there is still a lack of comprehensive budgets for large and wide rivers probably due to the complexity of the phenomena and the still poor field observations. This study aims to assess a first attempt of a short-term LW budget in a large gravel-bed river (Piave River, Italy) as a result of a significant flood occurred in November 2014 (RI ≈ 6 years).

Study Area

The study has been carried out in Piave River, a gravel-bed river located in the North East of Italy that flows for 220 km from Alps to Adriatic Sea, draining an area of 3899 km^2. The study area is a reach 1-km long located in the middle course of the river, where the morphology is in transition between wandering and braided channel pattern. The last flood event that exceeded the bankfull discharge (700 m^3 s^{-1}, Comiti *et al.*, 2011), occurred in November 2014 recording a peak of about 1329 m^3 s^{-1} (R.I ≈ 6 years).

Materials and Methods

According to the framework proposed by Martin & Benda (2001), the LW budget was calculated for a short term period therefore the wood decomposition was not considered. Moreover, as the first attempt of the study the loss of wood due by overbank deposition was provisionally omitted. The LW budget equation applied in this study reduces on:

$$\Delta S = [\ I_{be}(\Delta_x) + (Q_i - Q_o)\ ]\ \Delta_t \qquad \text{(Eq. 1)}$$

The input of LW by bank erosion (I_{be}) was obtained through previous field surveys on standing tree vegetation (numerousness, volume and position) and monitoring of riverbanks with Differential Global Positioning System (DGPS) before and after the flood. Fluvial transport of LW into (Q_i) and out (Q_o) of the study reach was calculated measuring all pieces of wood within the bankfull width before and after the flood. Both individual LW as well as LW in jams, characterized by a diameter greater than 0.10 m and/or a length greater than 1 m (Morris *et al*., 2007), were considered. The volume for each piece of wood was calculated adopting the cylinder formula (Benda *et al*., 2002), the geographic position of all pieces was registered, and a numbered metal tag was implanted in order to allow the identification.

Results

In Table 1 are summarized the preliminary results about the amount and characteristics of LW before and after the flood of November 2014. Data collected after the flood revealed a greater amount of wood stored in the study reach, both in terms of quantity and volume. The total number of wood pieces changes from 204 to 331, with a decrease in the number of individual LW and an increase of LW in jams. The number of jams presents before and after the flood is quite similar, however, there is a considerable variation in the mean number of individual LW forming the jams, it changes from 3.45 to 9.03. Finally, the total LW volume shows an increase of 157.32% shifting from 42.69 m^3 km^{-1} to 109.86 m^3 km^{-1}. Considering the LW dynamics in terms of budget, the input of LW from upstream is equal to 102.06 m^3 km^{-1} (329 LW), whereas bank erosion introduced just 0.18 m^3 km^{-1} of LW into the study area. The final component of the budget, the quantity of LW leaving the study area, is equal to 35.07 m^3 km^{-1} (198 LW), corresponding to the 82.15% of the total LW population previously stored in the riverbed (Fig.1).

	Pre flood	Post flood	Δ %
Total n° of wood pieces	204	331	+ 62.25
N° of LW individual	97	65	- 32.99
N° of LW in jams	107	265	+ 147.66
N° of jams	31	29	- 6.45
N° of LW per jams (mean)	3.45	9.03	+ 161.74
Total LW volume (m^3 km^{-1})	42.69	109.86	+ 157.32

Table 1: characteristics and volume of LW stored in the study reach before and after the November 2014 flood event

Discussions and Conclusions

The preliminary results of the LW budget for the Piave River due to a significant flood event, indicate that almost all LW stored in the riverbed is subjected to be remobilized. The 82.15% of LW has left the study area, the 17.73% is involved in the internal displacement and the remaining 0.12% is remained in the original location. Regarding the input of LW, the fluvial transport exerted a fundamental role (99.83%) whereas the LW recruited by bank erosion in the study segment was negligible. Overall, considering the difference between the input and output factors, the variation in the LW population stored in the riverbed is equal to + 157.32%, corresponding to + 67.17 m^3 km^{-1}. However, due to the complex dynamics that affect the LW budget, future improvements of this methodology will be desirable. Will be useful to extend the spatial scale in order to evaluate more bank erosion processes as well as introduce the output of LW through overbank deposition, especially significant in the case of floods exceeding the bankfull stage.

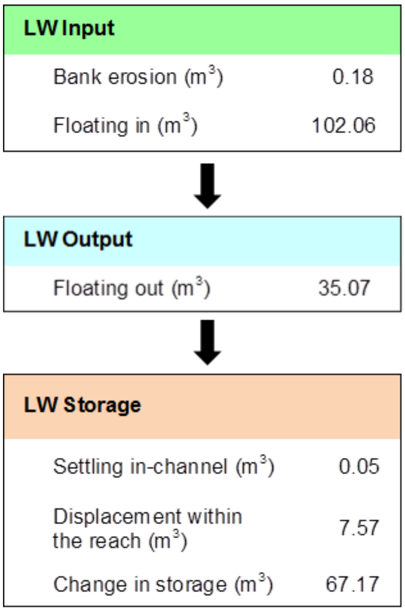

Figure 1: short-term LW budget for the Piave River

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Flume modelling of large wood dynamics in braided channels characterised by different vegetation occurrence

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Abstract

This work investigates wood dynamics in braided streams through physical modelling in a mobile bed laboratory flume subject to a series of cycles of flooding, wood input, and vegetation growth. Three parallel channels (1.7 m wide, 10 m long) filled with uniform sand were used to reproduce braided networks with constant water discharge and sediment feeding. Wood dowels with and without simplified rootwads were regularly added at the upstream end of each flume at different input rates. Moreover, the effect of living vegetation was explored by reproducing weekly cycles of seeding of the exposed bars surfaces in a second set of runs. Temporal evolution of wood deposits, and vegetation establishment and erosion rates were monitored by series of vertical images that permitted the recognition of individual logs. The specific objective of the work was to characterise wood storage and turnover as a function of wood input rate and to assess how different vegetation scenarios impact these dynamics.

Results

Results of the unvegetated runs show that wood tends to disperse in small accumulations (<5 logs), with higher spatial density on top of sediment bars, and is frequently remobilised due to the intense morphological changes (see Bertoldi et al., 2014 for more details). The amount of wood stored in the channel depends on log input rate through a non-linear relationship, and input rates exceeding approximately 100 logs/hr determine a sharp change in wood dynamics, with higher storage volume and augmented formation of large jams (>10 elements) that are less prone to remobilisation. Presence of root wads seems to play a minor role on wood deposition, but it reduces the average travel distance of logs. Turnover rates of logs were independent of wood input rate and largely resembling the turnover rate of exposed bars. In the case of the unvegetated runs, significant effects of wood on bed morphology were not observed, suggesting that interactions with fine sediments and living vegetation are crucial to form large, stable wood jams able to interact with bed morphology.

The second set of runs showed that the inclusion of vegetation in the experiments changes wood dynamics, in terms of both the quantity that is stored and the depositional patterns that develop. Vegetated banks increased channel stability, reducing lateral erosion and the number of active channels. This promoted the formation of stable wood jams, where logs accumulated continuously at the same locations during subsequent floods, reinforcing their effect on river morphology (see Bertoldi et al., submitted, for more details).

Discussions and Conclusions

The experiments have confirmed the important joint impact of riparian woodland and large wood on river channel form and dynamics, illustrating their aggregate effects on the morphology of river reaches and also the range of landforms that are constructed locally. However, our preliminary results showed relevant changes in wood dynamics for increasing wood input regime and vegetation density, pointing out the possible occurrence of specific thresholds, above which wood transport and deposition patterns may drastically change. These observations need further investigation through field and modelling analysis.

The feasibility of studying these processes in a controlled environment opens new possibilities for disentangling the complex linkages in the biogeomorphological evolution of the fluvial system and thus for promoting improved scientific understanding.

The experiments reproduced many forms and processes that have been observed in the field, from scattered logs in unvegetated, dynamic braided channels, to large wood jams associated with river bars and bends in vegetated, stable, single thread rivers. Figure 1 reports three examples of the central reach of the experiments, taken a) at the end of the unvegetated runs; b) one week after the first seeding cycle; and c) after the third seeding cycle. More details can be found in Bertoldi et al., 2014 and 2015.

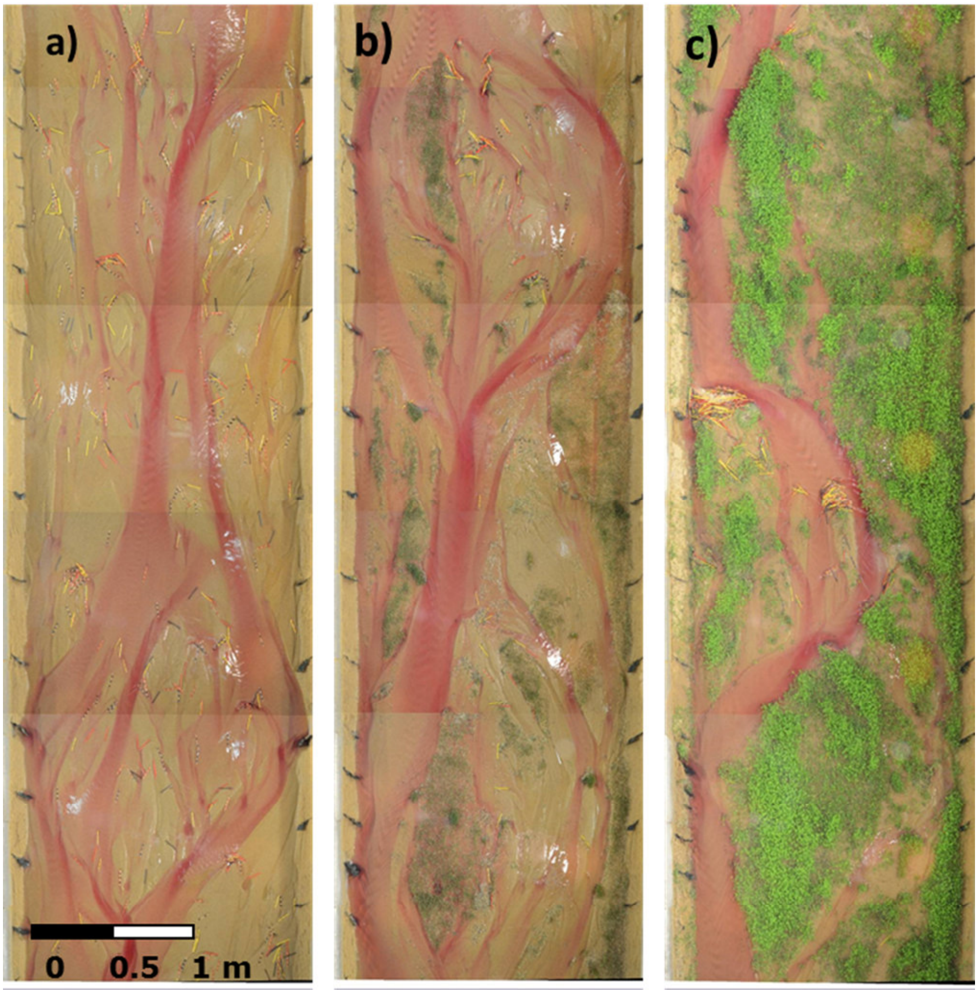

Figure 1: Vertical images of one of the three flumes at different temporal stage: a) at the end of the unvegetated runs; b) after the first cycle of seeding; c) after the third seeding cycle.

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Photographic mapping of wood dynamics in the gravel-bed, braided Tagliamento River, Italy

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Abstract

This work investigates large wood (LW) dynamics in two reaches of the gravel-bed braided Tagliamento River (Italy), characterised by a different occurrence of stable vegetated islands. Deposition and re-mobilization of large wood is monitored by a high temporal resolution photographic survey. Two digital reflex cameras, installed in April 2008, automatically acquire a picture every hour (during daylight). The dataset comprises now more than 50'000 pictures and allows a detailed analysis of wood dynamics as driven by floods of different magnitude. The aim of this paper is to provide a preliminary analysis of the amount of deposited wood, its stability, and re-mobilisation, as well as the timing of the changes. Wood dynamics are related to flood magnitude and a relationship between wood deposition and internal wood production by bank erosion is explored.

Methods

The dataset includes 25 floods ranging from small flow pulses to a 10-years return interval flood. A gauging station 15 km upstream of the study reach provided information on flow stage. In order to take into account the magnitude and duration of floods, we defined the potential sediment transport flux Φ as following the Mayer-Peter & Muller approach:

$$\Phi = 8\sum(h - h_c)^{1.5},$$

where h is the flow stage and h_c is the critical stage for sediment motion.

Relevant pictures were rectified, using 20 ground control points surveyed with a differential GPS, and LW deposits were manually mapped in GIS environment. Each flood event was then characterised in terms of the amount of new deposited wood elements and proportion of re-mobilised logs (figure 1). Only large wood deposited on bare gravel bars was considered, as picture resolution does not allow to identify wood in densely vegetated islands. This means the analysis does not allow us to quantify a full wood budget, and can give information on the new deposits, potentially leading to the formation of new pioneer islands.

Figure 1: Two pictures taken by the camera at Flagogna reach before and after a flood occurred in December 2009,showing the lateral erosion of a vegetated island and the associated deposition of large wood.

Results

Both reaches showed a high density of LW deposits on gravel bars with up to 630 LW elements identified on the 1-km long Cornino reach, and up to 100 in the exposed areas of the Flagogna reach. A large variability is observed, depending on flood occurrence, bank erosion, and availability of suitable depositional sites. The island-braided Flagogna reach showed on average a lower proportion of wood deposits on gravel bars. This can be related to the narrower width of the Flagogna reach, associated with a higher proportion of vegetated islands, which implies deeper and faster channels (Bertoldi et al., 2011). In general, we observed that a lower amount of wood is present after large floods, whereas a denser wood distribution occurs after moderate events.

Flood magnitude, quantified in terms of peak discharge and potential sediment transport flux, influences wood erosion. The proportion of remobilised wood elements shows a significant correlation with these two parameters, although a large scatter is present (figure 2).

Wood deposition is less related to flood magnitude, but depends on the occurrence of bank erosion. The area of vegetated bank eroded during each flood is the parameter better explaining the number of deposited wood elements, particularly when you sum the results of the two reaches (figure 3). This is in agreement with the observations by Bertoldi et al. (2013) and Welber et al. (2013), who find that in a complex braided network, eroded trees tend to travel a short distance, their mobility being reduced by the shallow flow on top of sediment bars.

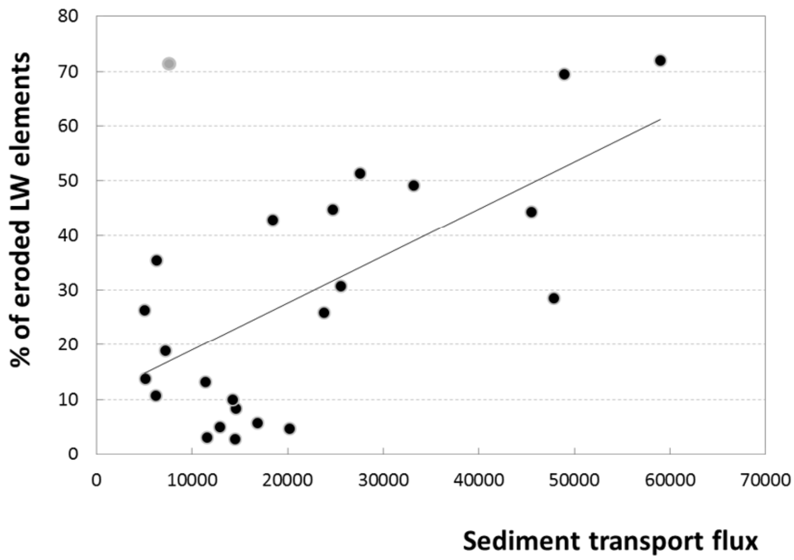

Figure 2: Relationship between proportion of eroded LW with the sediment transport flux of each flood, for the Flagogna reach.

Conclusions

This analysis at high temporal resolution and including 25 floods of different magnitude provides a valuable source of data and showed that wood deposition and remobilization are complex processes which, on relatively short reaches, cannot be fully explained by flood occurrence and magnitude. In particular, wood deposition depends strongly on local production by bank erosion. The inclusion of topographic data, in terms of bed elevation at which wood elements are deposited, could potentially add relevant information to better evaluate their stability.

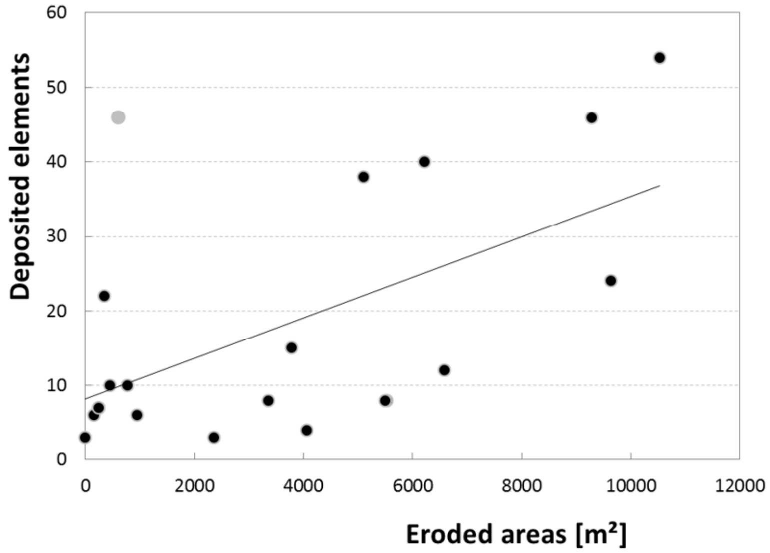

Figure 3: Relationship between number of deposited LW with the eroded area during each flood, for the Flagogna reach.

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Automatic imagery analysis to monitor wood flux in rivers (Rhône River, France)

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Abstract

In fluvial geomorphology, the use of ground imagery is increasing and produces large amounts of valuable data at high frequencies. This study explores the use of automatic imagery to quantify the wood delivery from the upstream Rhône River catchment (France). Pieces of wood are trapped by the dam and a raft grows up through time in the reservoir. Wood is mechanically removed 3 to 4 times per year so that the wood delivery from upstream can be compared to the raft surface observed on pictures. An Axis 211W camera was installed in 2011 to capture oblique images of the Genissiat dam reservoir every 10 minutes. A method to automate image processing was developed, based on random forests for distinguishing wood and water pixels according to their radiometric and textural properties. Images were orthorectified to allocate to each pixel a surface proportional to its real surface and to estimate the raft area. A statistical relationship between the weight of wood extracted and the raft extent prior to the extraction was established to predict the quantity of wood on each picture. Comparing the wood raft change in surface area with the Rhône River hydrological series allowed defining flow events that are critical in terms of wood delivery. This study illustrates the efficiency of ground imagery analysis to monitor stream processes occurring at short time scales. Ground imagery enables to overstep aerial and satellite imagery confines and to change or multiply vantage points. But factors disrupting the quality of shots and so the image processing are frequent.

Keywords: *ground imagery; high frequency; image processing; Rhône River; wood raft.*

Introduction

Since the early 2000s, in situ cameras are explored in fluvial geomorphology because they allow easy acquisition of close-range imagery at high spatial resolution, and at high temporal frequency. Datasets produced with such cameras were used to monitor the evolution of a wood raft stored in a reservoir, the impact of floods on gravel bed river morphology, river ice dynamics or bank erosion in cold regions (Bertoldi *et al.*, 2012). All these works were based on a time consuming visual analysis of pictures limiting the analysis to short periods or time-located events. Because large amounts of data can be produced by setting up automatic cameras in field, automation of the image processing is required for medium to long-term monitoring. For example, 14,600 images can be produced over one year, taking one image every 15 minutes between 8:00 AM and 6:00 PM. This paper proposes a method to automate processing of large datasets acquired over a few months to a few years at a frequency of 10 minutes to one hour. The challenge is to monitor stream evolution with very high frequency in order to better understand stream processes occurring at short time scales. To illustrate the method, it is applied on the case of wood flux prediction based on the observation of the wood extent in a reservoir through time from ground-imagery.

Study Area

The Rhône River is one of the biggest rivers in France with a 1,710m^3/s discharge. It is 812km long and finds it source in Switzerland. In its French part, the Genissiat dam (Figure 1) is the first hydro-electric dam that was built. It is located 50km downstream from Geneva and 160km upstream from Lyon. It is 105m high and 140m long at its top. The reservoir created by the dam is 23km long (Moulin and Piégay, 2004).

All pieces of wood coming from upstream are trapped by the dam. They are mainly provided by the two largest tributaries downstream of the Geneva Lake, the Arve River and the Valserine River. A wood raft grows up through time in the dam reservoir, which constrains the manager company of the dam (the CNR) to mechanically remove an average of 8.4 tons of wood pieces per year, 3 to 4 times a year***.***

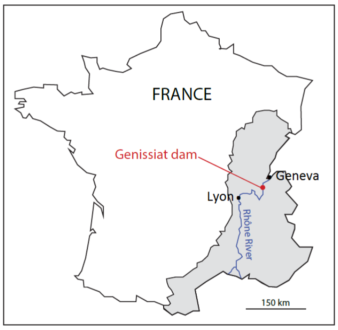

Figure 1: The Genissiat dam on the Rhone River catchment.

Materials and Methods

An Axis 211W camera was set up on the dam in February 2011, focusing on the reservoir and the wood raft. Images were taken every 10 minutes with a 480*640 pixels resolution. Image processing was performed with the R software. Several textural and radiometric parameters were extracted in all images along an orthogonal grid with 24*32 squares, 20*20 pixels in dimension each. Parameters were extracted from the RGB bands available and from the HSI bands that were calculated from Gonzalez and Woods (1992). These squares were automatically classified into *wood* or *water*. The values applied for the automatic classification were established from a learning sample, constituted of 91 images selected in the dataset both randomly and for their visual properties. A random forest (RF) was performed on the squares of the learning sample, that had been manually classified. An orthorectification process has then been realised with the Fudaa-LSPIV software, developed by IRSTEA. The thickness and density of the raft being assumed constant (Moulin and Piégay, 2004), its extent observed in each picture has been considered as a surrogate of the wood weight through time. The quantities of wood extracted by the CNR during ten operations were used to establish a statistical relationship between the total extracted wood weight and the raft extent observed at the time of extraction.

Results and Discussion

The RF provided very positive results in most cases, with 97% of good classification in the squares of the validation sample. The sensitivity and the specificity scores were respectively 0.98 and 0.95 (Begueria, 2006). The Figure 2a presents the number of squares automatically classified into wood depending on their manual label. The observed case is quite close to the ideal case and R^2 is almost 1. The Figure 2b presents the resulting surface predicted from this classification, depending on the observed case. The model efficiency is lower but quite good: $R^2 = 0.85$. The lowest classification efficiency occurred in the background of images, were the size of the squares is the biggest. Some images did not fit to the predictive model, notably the ones where reflects were clearly visible and produced an overestimation of the wood raft surface pixels.

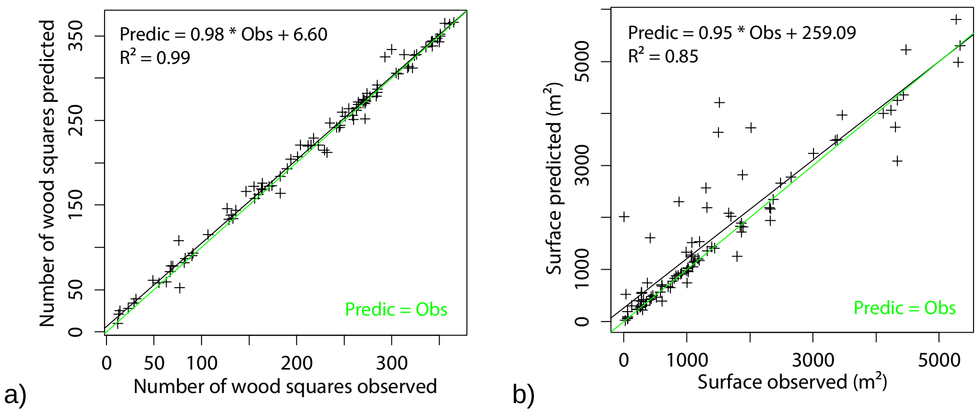

Figure 2: Number of squares automatically classified as wood (a) and surface of the raft predicted (b) compared to observed cases.

This method seems to be efficient to monitor a wood raft dynamics: first results show that periods of wood removal are well identified on time series. Wood raft area increases progressively during summer and fall 2013, after mechanical extractions events and during increasing discharge periods (Figure 3).

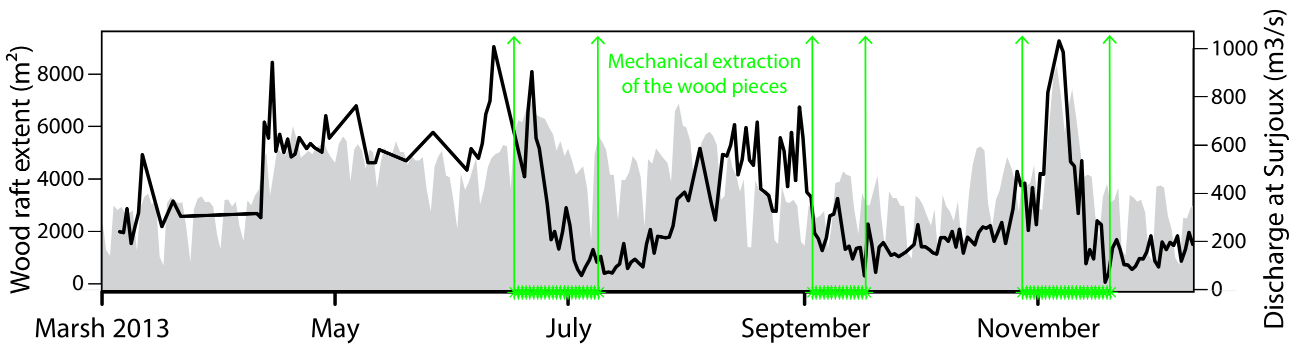

Figure 3: Time series of the wood raft surface predicted in the Genissiat dam reservoir and hydrogram of the Rhône River (in grey) 3.7km downstream of the dam (Surjoux station).

Conclusions

Automatic cameras seem fairly accurate to monitor fluvial systems. This approach is based on two main steps, the acquisition of images and their processing. The first step needs to be carefully considered because quality of pictures and so their processing depend on it. Cameras allow overstepping field study limits and aerial and satellite imagery confines and provide a good tool for fluvial system management, allowing the observation of rapid and stochastic phenomenon with high temporal resolution.

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Porosity Problems

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Abstract

Porosity, or void space, of logjams in streams can be highly variable due to differences in forest stand age and mechanisms of wood recruitment, stream sizes, transience of wood jams leading to variable infilling of organic material, and disturbance regimes. Knowing porosity values for logjams can lead to greater understanding of channel complexity and connectivity, has implications for management opportunities in fluvial systems with wood loads, and can help constrain carbon and wood budgets. Very few studies explicitly address the variety of porosity values in logjams, how porosity is calculated and assessed, and the effect such estimates have on carbon and wood budgets in streams across the world. We address specific field methods in porosity calculations and compare across multiple regions, forest types, and stream sizes: northern Canada, interior Alaska, and the southern Rocky Mountains in Colorado and Wyoming. Preliminary results suggest lower porosity values than those previously published, with large ranges of porosity even between intra-stream jams. We suggest the development of a universal field guide with which researchers and managers can use as a means of estimating logjam porosity that minimizes field time and efforts.

Keywords: *field methods, logjams, large wood, porosity estimation*

Introduction

Measuring the volume of wood in logjams and accumulations is important for ecological applications and wood and carbon budgets (Aufdenkampe et al., 2011; Wohl et al., 2012). This is most easily done by tracing an areal region around the wood and multiplying the area by its porosity and mean height. Unfortunately, porosities and heights of logjams can be extremely variable within and between study sites, leading to imprecise volumes. Published values of porosity have a wide range, with examples of ~90% porosity to ~66%, resulting in 10% and 34% wood, respectively (Thevenet et al., 1988; Manners et al., 2007). Estimating accurate volumes of wood in jams is difficult due to the difficulty of estimating jam porosities, particularly for studies with large spatial scales. We will compare methods to estimate porosity of logjams across three field sites: the Colorado Rocky Mountains in the USA, Northern Canada, and interior Alaska. We also present an idea for creating a logjam porosity guide, similar to field guides used to estimate channel roughness.

Study Area

Field sites from the Rocky Mountain region are located in Rocky Mountain National Park and Roosevelt National Forest, Colorado, as well as the Medicine Bow Mountains, southern Wyoming, and are second to third order streams flowing through subalpine forests. Study reaches in this data set represent a variety of forest stand age and management histories, including old-growth forest in undisturbed National Park land. Field sites in interior Alaska are along Preacher Creek, which is within the Yukon River drainage basin and has a drainage area of ~4000 km^2. In northern Canada, logjams have been measured along Great Slave Lake and along the Slave River, a large river with a drainage area of ~616000 km^2.

Materials and Methods

We use field data from four locations: two subarctic rivers, Great Slave Lake, and several mountainous headwater streams in the Rocky Mountains of Colorado to investigate porosity variability and measurement error. In Rocky Mountain sites, stream reaches, which were approximately 500m in length, were followed continuously and each logjam evaluated. For each logjam, approximate length, width, depth, percent organic matter, and a visual estimate of porosity was measured. In addition, each piece of wood greater than 1m in length and 0.1m in diameter was measured within the logjam. The total volume of individual wood pieces was then used to back-calculate porosity of each jam using volume dimensions measured for the entire jam. Visual porosity estimates were then compared with calculated porosity measurements for each jam in order to identify accuracy of visual porosity estimation, as well as the range of porosity estimates for logjams in Rocky Mountain streams. Three large logjams on pointbars were measured along Preacher Creek. We measured the area of each jam and took multiple measurements of jam height to obtain an average height of each jam. We estimated porosity using transects across each jam and with a visual estimate. Similar methods were employed along the Slave River and Great Slave Lake.

Figure 1: Example of Rocky Mountain logjam in old-growth forest with little difference between visually estimated porosity (0.60) and calculated porosity (0.57) using volume of individual wood pieces and dimensions of jam.

Figure 1: Example of Rocky Mountain logjam in area with previous forest fire with large difference between visually estimated porosity (0.20) and calculated porosity (0.69) using volume of individual wood pieces and dimensions of jam. Student on left for scale.

Results

For Rocky Mountain sites, a total of 194 jams were evaluated. Average porosity values, depending on method, ranged between 0.37 and 0.45, with ranges from zero porosity up to 0.89. Visual estimates of porosity lie in the similar range and average as calculated values, with visual estimates typically underestimating porosity by on average 7 percent (Figures 1 and 2). In interior Alaska along Preacher Creek, porosity measurements of jams using a transect method were 0.51, 0.28, and 0.54, with visual estimates of 0.50, 0.40, and 0.62, respectively. The average heights of the three jams were all approximately 1 m. For the Great Slave Lake in Canada, wood drift piles ranged from 0.3 m to over three meters in height, with similar ranges found by Boivin et al. (2015). On the Slave River in northern Canada, logjam porosity is highly variable depending on the degree of imbrication, which is controlled by ice-push or water deposition, and amount of smaller branches, twigs and wood pulp draped on top.

Discussions and Conclusions

Logjams in Rocky Mountain streams have lower porosity values than porosity estimates of previous studies, indicating the variability of porosity of logjams across different regions. Furthermore, porosity of individual, persistent logjams may diminish with time as organic material moving downstream fills in void space. The height and porosity of logjams in the sites in northern Canada are also highly variable, while the sites in interior Alaska are more consistent across a small sample size of three. Visual estimates of porosity appear to be relatively similar to other methods of determining porosity. Our study shows that while visual estimates of porosity can be relatively reliable, there is not a guide with which researchers can consistently visually classify porosity estimates. We call for the development of a field guide to logjam porosities, much like a stream roughness guide for Manning's n values. The wood in river research community would greatly benefit from a visual logjam porosity guide.

Acknowledgments

Field data from the Rocky Mountains was primarily funded by a National Science Foundation Grant as part of a larger, multidisciplinary project on the relationships between wood jams and ecosystem processes. We acknowledge Gus Womeldoprh and Reed Waldon for field assistance. Field data for the Preacher Creek data is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. DGE-1321845 and the National Geographic Society, with field assistance from Micah Nelson and Josh Rose.

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Impacts of an engineered log jam on turbulence and momentum extraction across discharges

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Abstract

Engineered log jams (ELJs) are commonly implemented to protect riverbanks from erosion and to increase hydraulic complexity for enhancing fish habitat. Despite their widespread application, few studies have investigated the effects of ELJs on the turbulent flow field. Thus, there is limited evidence of the actual benefits provided by the practice, or how the benefits vary with flow depth. This study presents modeling experiments of an ELJ composed of vertical and laterally-stacked posts, a design commonly applied to the outside of meanders. The goal of the study is to investigate whether and how the number and size of coherent structures, Reynolds stresses, drag forces, and energy spectra vary with discharge. A 2D hydrodynamic model (iRIC-SToRM) is developed based on field observations of the flow field. Results indicate that, at higher submergence depths, the ELJ primarily rearranges the spatial pattern of flow, resulting in more and smaller coherent flow structures, with some limited modification to the energy spectra and no discernible impact on Reynolds stresses. At low jam submergence depths, the impacts on the number and size of coherent flow structures and energy spectra are minimal, but a small and localized increase in the magnitude of Reynolds stresses is observed. Drag coefficients appear to vary more with discharge than with the addition of the ELJ. Results indicate that the ELJ can potentially provide hydraulic refuge for fish at higher flows habitat, but has limited benefit for modifying the flow field to reduce velocities or stresses responsible for riverbank erosion.

Keywords: *river restoration; large wood; hydrodynamic modeling; coherent flow structures;*

Introduction

Engineered log jams (ELJs) have been implemented to protect streambanks from erosion and to re-introduce habitat complexity to simplified channels (Abbe et al., 2002). ELJs have been shown to introduce flow resistance that reduces peak velocities and redirects the velocity core of meanders away from streambanks vulnerable to erosion (Daniels and Rhodes 2004). Habitat benefits are justified by their potential contribution to the development of eddies and more complex flow structures, which fish use for foraging (Fausch, 1984) and navigation and resting (Liao, 2007). However, while these turbulent features of the flow field provide the primary justification for ELJs, few studies have evaluated the impacts of large wood on energy dynamics of rivers, particularly as they vary with depth of submergence (but see Manners et al. 2007). As a result, ELJ designs generally rely on prior experience, professional judgment, and measurements made on idealized conditions in the lab (e.g. Wallerstein et al. 2001). This study investigates the observed and simulated flow field around two types of ELJs commonly applied to the outside of meanders. The study goal is to evaluate whether and how their impact on the number and size of coherent structures, turbulence statistics, drag forces, and energy spectra scale with discharge.

Figure 1: Photo of the engineered log jam on the Calapooia River, Oregon at 20% submergence, looking downstream.

Study Area

Field observations were made on the Sodom channel, a 30m-wide bifurcation of the Calapooia River, Oregon.

Materials and Methods

Velocity measurements, bathymetry, and water surface elevations were collected around a stacked-member log jam installed on the Sodom channel. The ELJ was installed as part of an effort to stabilize the channel follow removal of a low-head dam. The flow field around the ELJ was surveyed using an ADCP mounted to a raft at a discharge of 9 m^3s^{-1}. In addition, water surface elevations were observed over a range of discharges that represent submergence depths of 1%, 20%, and 60%, which were used in model calibration.

The flow field around the jam was simulated in iRIC-SToRM (Simões 2014), an unsteady, depth-averaged 2D hydraulic model that applies an unstructured mesh to solve the shallow-water Navier-Stokes equations. The flow field was simulated at calibrated discharges of 5.6 m^3/s, 32.6 m^3/s, and 123.3 m^3/s and validated at a discharge of 9.0 m^3/s. Model fit was quantified as differences between simulated and observed WSEs using the root mean squared error (RMSE). To directly evaluate the effect of the ELJ on the flow field, each discharge scenario was comprised of a simulation that included representation of the ELJ as topography in the model mesh, as well as a simulation with the ELJ removed from the mesh by connecting bank lines at consistent slopes upstream and downstream of the ELJ.

Model results were post-processed in Matlab to 1) conduct proper orthogonal decomposition (POD) using a closed streamline algorithm (Chen et al. 2012) for identifying the size and number of coherent flow structures, 2) calculate Reynolds stresses to quantify the magnitude and direction of turbulent fluctuations representing momentum exchange across a given plane, 3) calculate maxima of spectral energy from Gaussian wavelet analysis to the length scale of energy-containing eddies, and 4) calculate drag coefficients by resolving momentum loss across the 77m long control volume around the ELJ.

Results

As discharge increased, the number of vortices and the area affected by vortices declined, both with and without the ELJ. The presence of the ELJ shifted the size distribution of vortices toward more numerous, and smaller vortices (Figure 2), an effect that was most pronounced at high discharges. Corresponding shifts in the energy spectra were also observed.

Flow was deflected around a key member of the ELJ that extended into the flow field, producing an increase in velocity and Reynolds stress around the tip of the jam at low flow. Spatial patterns and magnitudes of Reynolds stresses were unaffected by the ELJ at intermediate and high discharge.

Finally, drag coefficients for the jam were low for scenarios with and without the ELJ, and differences among them appeared to be more correlated (negatively) to discharge than to the presence of the ELJ.

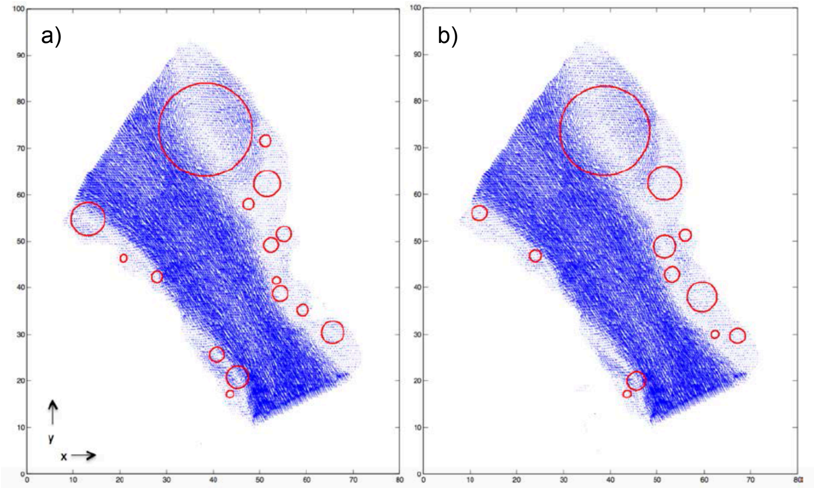

Figure 2. Vector plots for the a) ELJ and b) no ELJ simulations at 123 m^3s^{-1}. Vortices identified by POD illustrated with red circles, with the diameter of the circles scaled to the diameter of the vortices.

Discussions and Conclusions

The results provide some evidence that the ELJ does contribute to turbulence generation at higher discharges, which may result in conditions that are more favorable for fish seeking refuge. However, the finding that velocity and Reynolds stresses in the region of the ELJ were only affected during low flows contrasts with findings of Daniels and Rhoads (2004) that large wood in meander bends affected the magnitude and position of the high velocity core at all flow stages. This result, along with the lack of variability in drag coefficients, suggests that this structure acts as little more than organic rip rap, providing bank protection as a erosion-resistant lining, but doing little to extract momentum or alter the energy dynamics of the river.

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Large Wood Precision Prototyping and 3D-Hydraulic CFD Modelling to Evaluate River Processes and Enhance Engineering Guidelines

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Abstract

Large Wood (LW) has been widely used in stream and watershed restoration projects due to the many ecological benefits it offers. Its use in streams, however, has unresolved challenges with regard to its impact to stream morphology, safety and lack of design guidelines. Laboratory or field studies of LW characteristics is difficult due to irregular nature of LW structure geometry. However, using computational fluid dynamics (CFD) modelling calibrated with physical flume based replication allows for more reliability of complex hydraulics. Although, CFD modelling of LW has its own challenges: the difficulty of mesh representation and the combined comparisons lack reliable and practical 3D flow and mobile-bed models. In this paper, LW research and development partnership between the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and the Yurok Tribe is described in which a combined laboratory flume – physical modelling, CFD - numerical modelling, and field study replication approach is used to understand the hydraulic flow fields around LW. In addition, morphological changes induced by LW will be studied using in-river quantitative comparisons between CFD and field results to assist in the verification and validation of the CFD model (the computational strategy is outlined). The latest Terrestrial Laser Scanner (TLS) is used to obtain LW geometry in addition to stream bathymetry and topography. The geometry is processed so that LW surfaces are replicated and are processed into a stereolithography (STL) 3D solid model file. The STL surfaces are then used to generate a suitable 3D mesh in an automated manner for further comparisons with the 3D numerical modelling environment. Finally, we describe an integrated 3D flow and mobile-bed CFD model that adopts the 3D mesh as input and performs the computational modelling. A sample case is used to demonstrate the above processes.

Keywords*: 1. 3D Hydraulic Modelling; 2. Computational Fluid Dynamics (CFD) 3. Engineering Guidelines 4. 3D Scanning*

Introduction

Many river restoration projects have focused on creating flow and substrate complexity since studies have found that flow and habitat complexity is positively correlated with habitat quality (Smith et al., 2006). Large Wood (LW) and Engineering Log Jams (ELJ's) are an effective way of creating habitat complexity for aquatic species such as salmonids and has been widely used in stream and watershed restoration projects (Pess et. al., 2013; Jones et. al. 2014). Its popularity in ecohydraulics is due to the many ecological and morphological benefits it creates (Abbe and Montgomery, 2003). LW has a strong influence on local channel hydraulics leading to pool and bar formation and sediment storage (Eaton et. al., 2012). Flow resistance in rivers and its relationship to roughness and form drag is an important component to channel morphology (Buffington and Montgomery, 1999; Leopold et al., 1964). The field of hydraulic engineering has also shown to accurately predict channel scour associated with LW (Abbe and Montgomery, 1996). There is a need to better understand the flow and geomorphic processes induced by the placement of LW related to critical habitats using quantitative morphological assessments or structured design guidelines.

3D high resolution CFD modelling has been in popular use for research purpose in ecohydraulic studies (e.g., Kang and Sotiropoulos 2012). Its practical use in ecohydraulic assessments of restoration projects has also gained acceptance (e.g., Nicholas and McLelland 2004; Shen and Diplas 2008; Khosronejad et al. 2012). However, CFD modelling for hydraulic and geomorphic assessments due to LW is rarely carried out since mesh representation of complex LW shapes can be a daunting task and simulation of such flows is very challenging (Carney et al. 2006). Limited reviews were provided by Papanicolaou et al. (2008) in the general river simulation areas but no review was found by the present authors in the LW modelling area. One of the few modelling attempts was reported by Allen and Smith (2012) who applied a 3D CFD model to quantify the numerical effect of LW geometric simplifications on the surrounding flow field. Specifically, the local velocity and turbulent kinetic energy were numerically computed to evaluate three successively refined LW geometries. The study showed that oversimplifying the complexity of a LW can result in significant overpredictions of both velocity magnitude and turbulent kinetic energy. It also pointed to the need of high resolution modelling of LW flows. In this paper, we describe a recent research and development program initiated at the U.S. Bureau of Reclamation which aims to develop a high resolution CFD modelling tool to predict the flow field around LW and the morphological changes (scours) induced by LW. The study is accompanied by a field study at the Trinity River, California where many restoration projects have been carried out with the use of LW. The ultimate purpose of the project is to develop a practical CFD tool that may be used by engineers to assist LW design in stream restoration projects.

Materials and Methods

Wood jams and LW are extremely difficult to represent in computer modelling or laboratory experiments based on their complexity and irregular shapes (Smith et. al 2010). LW in rivers is typically found in chaotic forms with various orientation and sizes of logs, branches, roots, and slash materials forming an array of interwoven geometries. This collection of geometries presents a challenge when trying to replicate as a 3D solid model. With the recent advancement in laser scanners technologies the ability to capture complex objects in three dimensions is becoming feasible. Utilizing stationary terrestrial LiDAR scanners deployed in the field we are able to capture high resolution point cloud data made up of millions of 3D points of LW structures that were recently constructed for river restoration applications. An example is shown in Figure 1 with one of the restoration projects on the Trinity River.

Figure 1. *Constructed LW jam on the Trinity River – ground photo (left) compared to LiDAR scan (right)*

A process of precision prototyping is used by taking the raw 3D point cloud is importing it into the computer environment to serve as the foundational dataset for solid modelling, reverse engineering, and replication of the LW elements. Working with the data and geo-referencing multiple scans into a seamless point cloud can be time consuming and tedious. Even with state of the art computer software the point cloud needs to be edited and refined before developing a 3D solid. There are many software packages available that can perform these functions but understanding the project goals/objectives in relation to the software's limitations and capabilities is critical. For this research multiple software packages were operated. Post processing survey software of Trimble Realworks was used as the tool for scan registration and initial editing; Geomatic software by 3D systems called DesignX was used for point cloud manipulation into a water tight solid referred to as stereolithography or STL format. The workflow of developing the STL is one that has multiple steps and could be considered more of an artistic process rather than a set of standard commands. The power of the DesignX software is that it can use the point cloud data and wrap a best fit mesh around it; the user can perform various manual and automated manipulations to get a best fit surface model that is exported into STL format. Figure 2 below shows an example workflow from a 3D solid model of a single wood generated from a 3D point cloud.

Preliminary Results

The 3D flow and mobile-bed sediment transport model of this project consists of a flow module and a mobile-bed module. The 3D flow module is based on the U2RANS model developed by Lai et al. (2003) for river engineering applications. U2RANS adopts the unstructured mesh formulation applicable to arbitrarily shaped cells as developed by

Lai (2000). It solves the 3D turbulent flow equations and utilizes a collocated and cell-centered storage scheme with a finite-volume discretization. Due to the use of flexible mesh cell shapes, the automated mesh generator may create more efficient meshes by applying local mesh refinement, mesh cut-out by solid boundaries and other mesh generation techniques which are otherwise unavailable with a CFD model using fixed-shape meshes. The mobile-bed sediment transport module will be based on the Reclamation's latest sediment modelling methodology (Lai and Greimann, 2010; Lai et al., 2011). Technical details of both flow module U2RANS and sediment module may be found in the relevant papers and are not repeated here. The 3D mesh over a single wood element in Figure 2 is used by the 3D model and a flow over a single LW element is simulated as a demonstration. A water velocity of 1.0 m/s is assumed to flow over the LW rootwad from left to right and the predicted velocity flow field is shown in Figure 2.

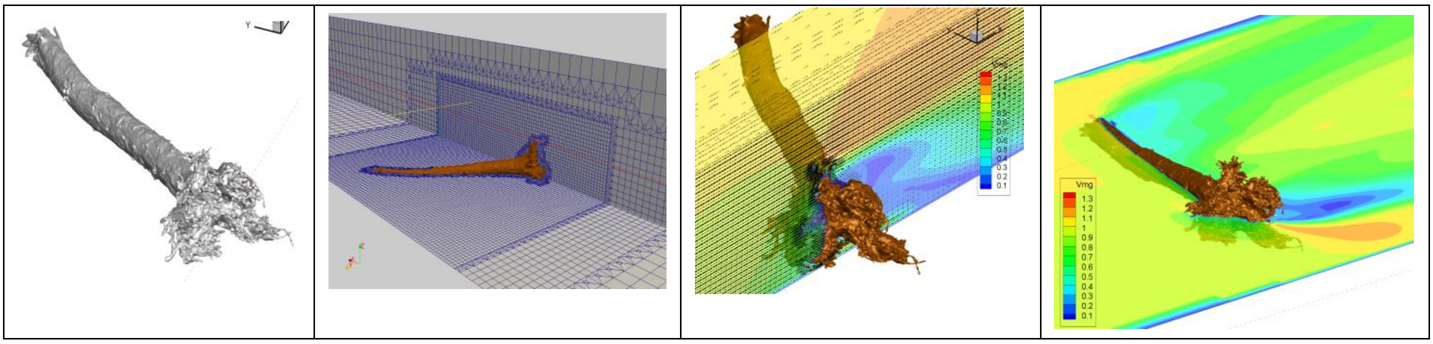

Figure 2. *Simulated flow field around a LW element as a demonstration case (3D solid, 3D mesh domain, velocity flow vectors)*

Conclusion

This Large Wood research and development is a collaborative effort between the US Bureau of Reclamation, US Corps of Engineers, and the Yurok Tribe. The initial research step is to perform a detailed calibration by comparing the results between a physical flume model and the exact replicated numerical 3D CFD model. This approach will provide detailed understanding of the complex hydraulics within the flow field that are induced by LW between laboratory and computer predicted environments. The comparison results between the physical model and the exact replicated numerical model will allow for proper calibration before the LW is introduced into a field application. The second phase of the research is to perform a field study research to assist in the validation and verification of the CFD model and examine the effects of LW in riverine environment. The field study will focus on the prediction of morphological evolution changes through erosion and scouring forces induced on the bed and bank topography in the river by the LW. The overall research program is still in its early stage; however, the approach described above by comparing the hydraulic results between a physical model in a controlled laboratory flume with the predicted results from exact 3D CFD numerical model will provide restoration practitioners detailed understanding of complex hydraulics and engineering considerations when using large wood as design elements in rivers.

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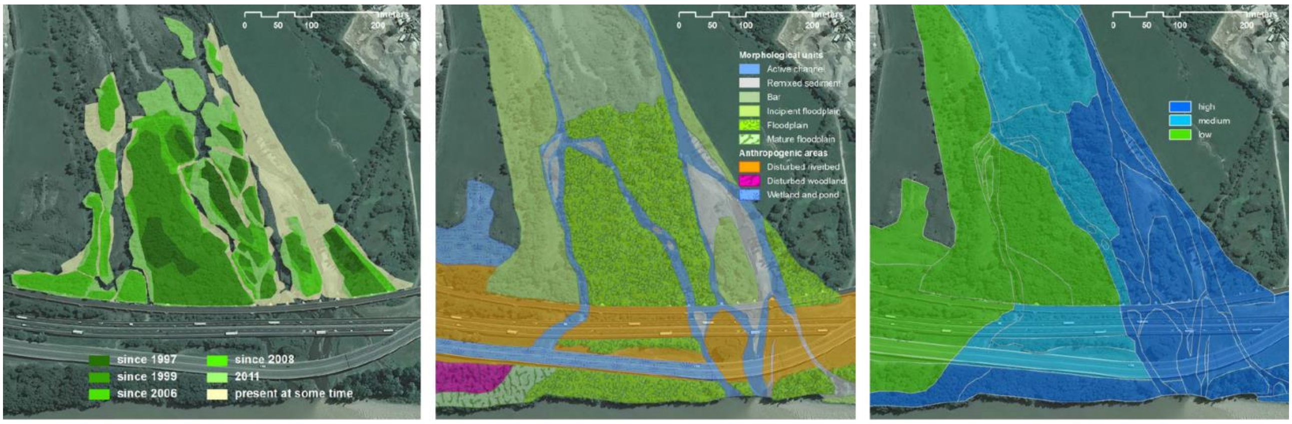
TOPIC 4 – Wood perception and management

Keynote speaker: **Arturo ELOSEGI**

Presentation title: The deception of perception: managing managers in an overpopulated world

Short presentation

Our goals in river conservation clash against the deception of perception: from the general public to high-level managers, misperceptions on the trends in river status abound. These include the perception that rivers are improving greatly, that floods are caused by lack of management, that "harnessed" rivers are best, and that changes in attitude towards nature conservation are for oncoming generations. The swift worldwide decline in freshwater biodiversity and the projections for human population demonstrate these perceptions to be wrong and stress the need for more ambitious river conservation. Thus, river perception is not a fixed constraint of our restoration projects, it is something to be managed.



From left to right: persistence of riparian vegetation across the years; 2014 morphological map; propensity to export LW

(In: *Management plan for riparian vegetation at the confluence of the Torrente Avisio river in to the Adige River. G. Trentin & G. Fossi*)

Sampling riparian vegetation and morphology with cross sectional transects: first results from three North-eastern Italian rivers

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Abstract

This study investigated woody riparian vegetation and geomorphology in three gravel-bed rivers (North-East Italy) affected by different intensities of human pressure. To characterize the links between riparian vegetation and morphological settings, the analysis were carried on at least one braided and one wandering sub-reach along each river. A total of 710 plots (4×4 m) along eighteen cross-sections (266-1000 m long) of the floodplain extent were surveyed. Morphological characteristics, stand and species composition have been analysed. Preliminary results suggest that the composition and characteristics of the riparian vegetation of the three fluvial ecosystems and the gradients between the geomorphic units in morphological variables have been strongly affected by the human pressure. There are relevant differences in the species composition of riparian woody communities, the elevation, and the geomorphic persistence of floodplains, islands and bars between the rivers. This will have implications on the forest management and conservation planning of riparian habitats.

Key words: *riparian vegetation, gravel bed river, Tagliamento River, Piave River, Brenta River, geomorphology, human disturbance.*

Introduction

Riparian vegetation interact with rivers increasing bank strength (Van de Wiel and Darby, 2007), altering flow velocities and direction (Nepf, 2012; Zong and Nepf, 2011), and influencing fluvial style and channel pattern (Millar, 2000). In turn, physical processes controlling river dynamics influence the main characteristics of riparian vegetation (Hupp and Osterkamp, 1996). The woody riparian vegetation is usually related to hydrogeomorphic conditions because tree and shrub species have different tolerance to disturbance factors such submersion, erosion and deposition (Tabacchi *et al*., 1998; Corenblit *et al*., 2007). Also the human pressure can strongly affect the characteristics, types and distribution of riparian vegetation (Hupp, 1992; Shafroth *et al*., 2002). We used cross-sectional transects to assess the distribution of woody riparian vegetation among three fluvial ecosystems characterized by different rates of human pressure. The aim was to test the differences in riverine vegetation structure between three gravel-bed rivers along a gradient of human disturbance.

Study area

The study was conducted along seven different sub-reaches of the Brenta, Piave and Tagliamento rivers (North-eastern Italy). These rivers are comparable in terms of size, climate and geological setting, but they differ for the presence and significance of human structures and interventions. The hydraulic regime of Tagliamento River is characterized by irregular discharges, high sedimentation load and high dynamism. It is one of the most intact and less disturbed rivers in the Alps. The Piave River's study reach is transitional between wandering and braided morphology, it is characterised by erosion and control works, but the course is not deviated or embanked. The Brenta River flows between the lowland and the alluvial plain. Its basin is affected by dams, hydrological derivations and embankments.

Methods

Eighteen cross-sections representative of their corresponding sub-reach were topographically surveyed in 2010, using a DGPS (average accuracy ± 0.025 m). The length of the cross-sections ranged from 266 to 1000 m. Along the cross-sections, 4×4 m plots (n=710, at least 35 plots for each sub-reach), spaced 10 m from each other, were surveyed. All woody species found on plots were recorded. A total of 393 plots had at least one woody species. The discrete geomorphic units where the plots lied was classified into three types (floodplain, island, bar) thanks to field recognition and remote sensing. We performed a preliminary analysis using box-plots for elevation above thalweg and geomorphic persistence and an IndVal analysis (De Cáceres, 2013) to test the alliance of woody species to any one of the river.

Results

The figure below summarises the differences in elevation above thalweg and geomorphic persistence among the geomorphic units within each river.

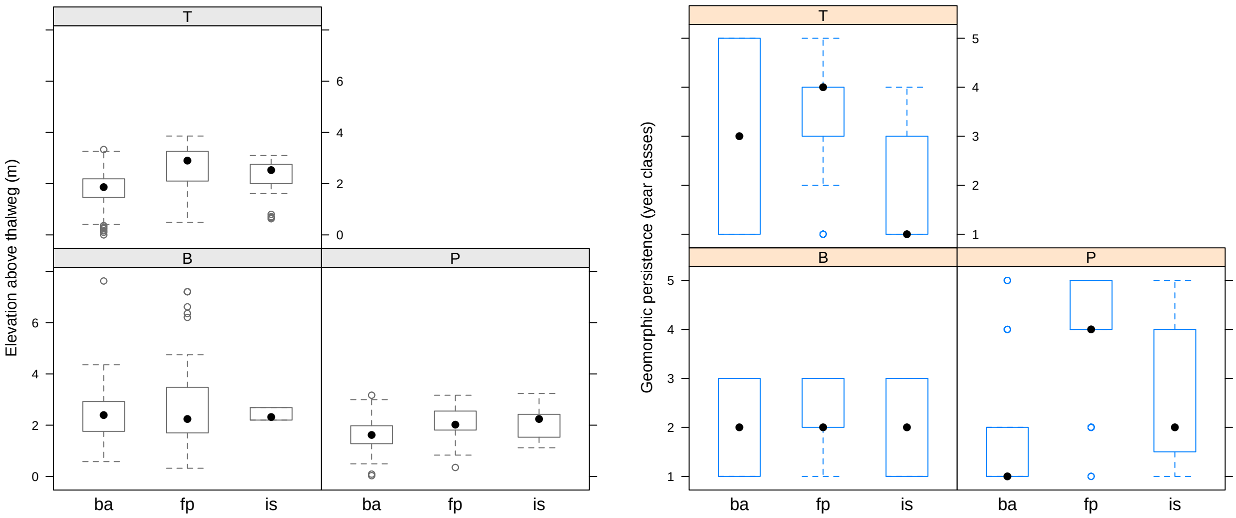

Figure 1: Box-plots showing elevation above thalweg (left) and geomorphic persistence (right) in three types of geomorphic units (ba: bar, fp: floodplain, is: island) belonging to three rivers (T: Tagliamento, B: Brenta, P: Piave) with different levels of human pressure.

Tagliamento River displays a gradient in elevation above thalweg where floodplains > islands > bars and in geomorphic persistence where floodplains > bars > islands, due to frequent flooding and sediment transport. On the contrary, Brenta and Piave rivers show similar elevations between geomorphic units. Geomorphic persistence changes among geomorphic units according to the order floodplains > islands > bars in Piave river, while in Brenta river they have all the same persistence. Compared to the other two rivers, Piave River has an higher number of indicator species, which are related to mature communities, like *Fraxinus excelsior* and *Quercus robur*. The vegetation of Brenta river is poorly characterised and only by *Berberis vulgaris*. Finally, Tagliamento river vegetation is characterised by a set of species indicators of gravel-bed habitats like *Hippophae rhamnoides*. Two species are associated both to Piave and Tagliamento rivers (*Alnus incana*, *Fraxinus ornus*), while *Salix purpurea* is associated to Brenta and Tagliamento rivers.

Discussion and conclusion

The vegetation of Brenta River is simplified due to the impact of embankments. The Piave River has a remarkable higher persistence age which allows a varied vegetation to develop. However, the most natural Tagliamento River is mainly characterised by species typical of the gravel-beds where the developed floodplain vegetation is less represented. This implies that an higher intensity of human disturbance, providing that banks are not manmade, may favour the development of communities on higher floodplains which are longer persistent than in natural conditions. However, the natural sediment dynamic would favour more xeric vegetation and limit its development. This should be recognised in the future forest management and conservation planning of riparian habitats.

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Towards a robust assessment of bridge clogging processes in flood risk management

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Abstract

In recent years intensive research dealing with the triggers and mechanisms of wood-clogging at bridges and the corresponding impacts on flood risk was accomplished at the University of Innsbruck. A large set of laboratory experiments in a rectangular flume at the scale 1:20 was conducted. The present paper attempts to provide a brief overview of the tests and its main findings. Further, based on these results, (i) a guideline for implementing bridge clogging scenarios into the hazard zone mapping procedure and (ii) specific constructional measures at and near bridges, that generally decrease the risk of clogging, are presented. Research on these topics was amongst financed with resources from the Autonomous Province of Bolzano and supported by a close cooperation with the Department of Hydraulic Engineering of the Province.

Keywords: *driftwood; bridge clogging; hydraulic scale model; flood risk management*

Introduction

In mountainous catchments, torrential hazard processes related to large wood (LW) are of substantial relevance for the assessment of flood risk. Focusing for instance on the procedure of hazard zone mapping, bridge clogging processes may have a major impact on channel hydraulics and inundation areas. The present work focuses on the processes related to the clogging of driftwood at bridges and thereby comprises a large series of experimental tests in the laboratory. Further, with regard to applicability in practice, a guideline for assessing processes and conditions leading to bridge clogging and results from testing bridge design modifications are presented.

Basic Dataset – Experimental Modelling

Basic data on the behaviour of driftwood at bridges, specifically focusing on clogging probability and the influence on channel hydraulics, were determined within physical scale model tests (1:20) in the hydraulic laboratory at the University of Innsbruck (Fig. 1, left). In roughly 2,800 experiments, influences of bridge type, water level, Froude number and driftwood parameters like log length and log geometry were analysed (Gschnitzer et al., 2013). Concerning the probability of clogging, basic relationships could be verified. Amongst, clogging probabilities generally increase with increasing length of the logs. The same effect applies to logs with branches, the appearance as bulks and, focusing on the bridge structure, the presence of piers. For the case of initially – without the influence of large wood (LW) – pressurized flow conditions, an increase in water level or in channel gradient basically leads to an increase in clogging probabilities. On the contrary, for low flow initial conditions, featuring water levels below the lowest bridge deck level, a decrease in channel gradient increases clogging probability. The most influencing parameters found are the water level, the bridge structure and the characteristics of the approaching driftwood ensemble (single logs or as a bulk). Two ranges of water level can be distinguished thereby: Whereas clogging is very unlikely for water levels lower than the bridge deck, in case of initially pressurized flow conditions, blocking of large wood (LW) is very likely. A bridge pier naturally increases the likelihood of clogging as the clear width of the channel decreases. The appearance of driftwood in bulks very likely leads to bridge clogging if the bulk is congested and its extent may exceed the bridge clearance (Gschnitzer et al., 2013). The impacts of bridge clogging on the channel hydraulics are mainly influenced by the initial (clear water) channel hydraulics and the characteristics of the driftwood ensemble. At supercritical flow conditions, blocking of logs likely leads to a flow transition upstream of the bridge. Subcritical conditions lead to backwater effects largely extending towards upstream. The reduction of discharge capacity in the channel is significantly influenced by the appearance of small particles (leafs, small branches, sediments) in the clogging matrix. A high percentage of small particles leads to a large capacity loss at the bridge section (Gschnitzer et al., 2013; Gschnitzer et al., unpublished (a)).

Guideline for the Application of Clogging Scenarios in Hazard Zone Management

The determination of a spatially and temporarily varying entrainment and transport of driftwood during floods is a complex endeavor. Empirical, GIS-based and numerical models were developed in recent years (Rickenmann, 1997; Mazzorana et al., 2010; Comiti et al., 2012; Ruiz-Villanueva et al., 2014). However, large wood (LW) and effects corresponding to clogging processes influence flood risk (Gems, 2012; Schmocker & Weitbrecht, 2013). Against this background and based on the experimental results, a practical guideline is developed enabling the definition of clogging scenarios and a model-based consideration within inundation mapping. A five-steps-procedure allows for the evaluation of clogging risk for (i) a specific bridge and (ii) a specific hydrological scenario. Entrainment of driftwood, transport and detention in the channel are firstly assessed. Further, on the basis of general parameters as the clear dimensions of the bridge, the flood hydrograph (Fig. 1, right) and the presence of piers, clogging probability is analysed. In a next step, the reduction of the channel cross section caused by the potentially clogged driftwood is determined. An artificial reduction of the clear dimensions of the bridge by analogy to the model tests allows for the implementation of the clogging process in a numerical model. Following this procedure, resulting water levels, flow velocities and the extent of flooding include also hazard exposed areas due to clogging of bridges (Gschnitzer et al., unpublished (a)).

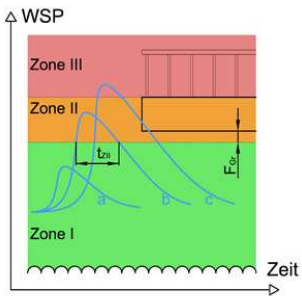

Figure 1: left: Scale model experiments on bridge clogging (1:20) at the University of Innsbruck; right: Example diagram from the guideline featuring assessment criteria for a standard bridge structure without piers (Gschnitzer et al., unpublished (a)).

Decreasing the Probability of Clogging

Aiming for a decrease in clogging probabilities and wood-related flood risk, a further issue of this work focuses on the effects of constructional measures at bridges. A set of design measures was experimentally analysed. Focusing on pressure flow conditions at the bridge structure, an inclined baffle mounted on the upstream face of the bridge was tested. It could be found that, compared to the basic experiments, in 12 % of the tests clogging probability increases, in 32 % of the tests no changes occur and in 56 % of the tests clogging probability decreases. The smooth and intake-like bridge characteristics trigger this behavior. A more specific view on the effects of the baffle with ΔP_{ABS} as the absolute difference of clogging probabilities is illustrated in Fig. 2. Further, the effects of two plates mounted on the channel embankments and leading to a channel constriction at the bridge were analysed. This measure aims for a change of the hydraulics in terms of lower water levels and correspondingly higher flow velocities and is thus only reasonable for subcritical initial conditions. Compared to the basic experiments a decrease of the clogging probability could be achieved in 58 % of the experiments (Gschnitzer et al., unpublished (b)). The tested measures were defined with a specific view to feasibility in practice and, thereby, to an adaption of existing bridges at a manageable effort.

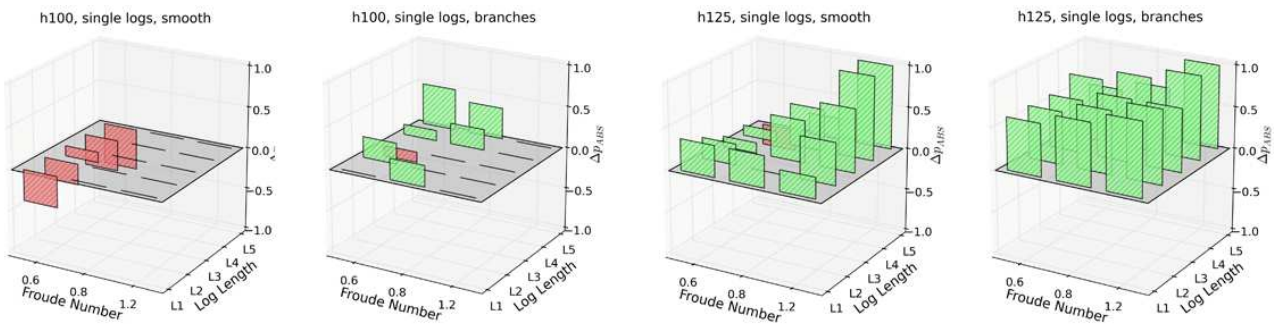

Figure 2: Effects of a baffle structure – absolute difference in clogging probabilities ΔP_{ABS} (Gschnitzer et al., unpublished (b)).

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Management plan for riparian vegetation at the confluence of the Torrente Avisio river in to the Adige River

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Abstract

A management plan for the riparian vegetation within the Special Protected Area (S.P.A.) IT3120053 “Foci dell'Avisio” was developed. The main objective of the management plan is to achieve a good trade-off between limiting the flood risk of the city of Trento and conserving the Nature 2000 priority habitat 91E0*. A gemorphological approach was followed. The management plan is based on the identification of different management units. For each unit addresses and rules are defined, concerning mainly the frequency and the intensity of the selective cutting of vegetation.

Keywords: *large wood; management plan; Nature 2000 habitat 91E0*; flood risk; Torrente Avisio.*

Introduction

A management plan for the riparian vegetation at the confluence of the Torrente Avisio river in to the Adige River was developed. The study area is the span of Torrente Avisio comprised within the S.P.A. IT3120053 “Foci dell'Avisio”, that is characterized by one of the greatest and best conserved alluvial forest in Trentino Province, northern Italy. The core of this alluvial forest is recognized to be a Nature 2000 priority habitat 91E0* “Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*)” (not published report; EC, 2013).

Figure 1: LW (Large Wood) within the main active channel of Torrente Avisio.

The migration of the Torrente Avisio's active channels gives frequently place to the erosion of the riparian vegetation. The resulting entrainment of LW worsens the flood risk of the city of Trento, 5 kilometers downstream, because of its potential to clog the bridges along the urban reach of the Adige.

The main objective of the management plan is to achieve a good trade-off between limiting the flood risk of Trento and conserving the priority habitat 91E0*.

Study reach

The study dealt with the downstream reach, and relative corridor, of Torrente Avisio, close to the outlet into Adige. The reach has a length of 1,700 m, the river corridor is delimited by artificial terraces built in the early '90s and has a width varying from 135 meters upstream to 350 meters downstream. The mean slope is equal to 1%.

The watershed area is 969 square kilometers, 78% of which es upstream the Stramentizzo hydropower dam that blocks all sediment and diverts directly to Adige the most part of discharges. The consequent hydromorphological alteration is the major cause for the actual alluvial forest extent.

The study area can be subdivided in to three subareas, from upstream to downstream:

A) a long braided stretch;

B) the core of the alluvial forest crossed by a main active channel and some smaller ones;

C) the floodplain of the Adige partly crossed and disturbed by the Torrente Avisio.

Figure 2: Representative images of the three sub areas: A) Torrente Avisio is eroding the artificial terraces that delimit the river bed; B) the core of the alluvial forest is crossed by some minor channels; C) the Adige's floodplain crossed by Avisio's main channel (coming from the right).

B) and C) subareas are separated by three long bridges that cross Torrente Avisio, with no concern about their clogging by LW.

Methods

The evolution of the reach in the past century was reconstructed analyzing historical maps, aerial photos and documentary evidence (Rinaldi et al., 2014). This first step led to identify three different phases of evolution: until the construction of the Stramentizzo dam, a following phase of adjustment characterized also by major disturbances directly in the river bed, and the actual phase.

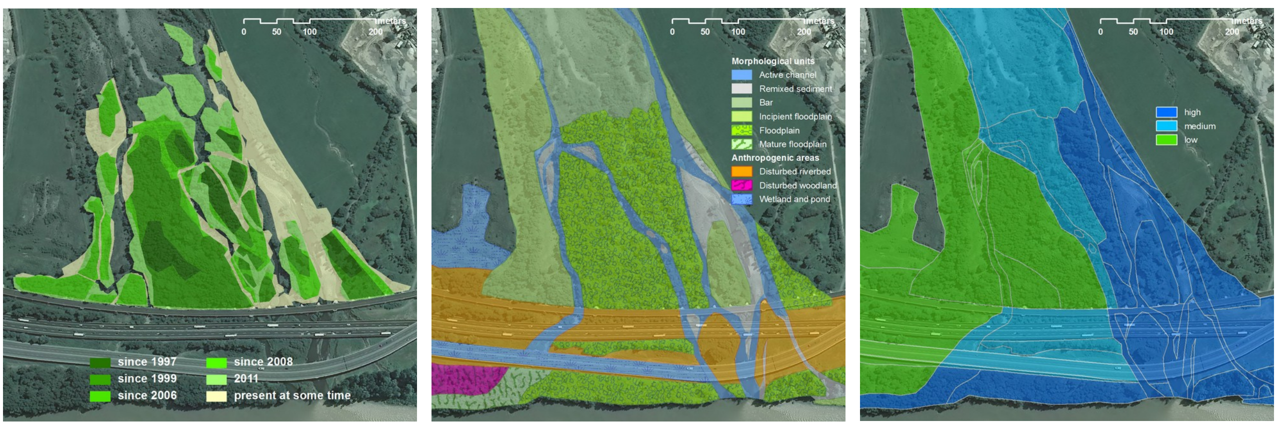

Figure 3: From left to right: persistence of riparian vegetation across the years; 2014 morphological map; propensity to export LW.

The most recent phase begun in the early '90s when a blank slate was created by heavy earthwork across the whole river corridor and lead to the development of the actual riparian vegetation. More detailed surveys were conducted for this phase aimed to reconstruct the active channels migration, terraces erosion and alluvial forest growth. The morphology was mapped for the year 2011 and 2014, the riparian vegetation and its relationship with morphological units was mapped and characterized in the 2014 (Hup & Osterkamp, 1996).

Results

A map of the propensity to export LW was developed analyzing the factors that influence the retention of LW (Gurnell et al., 2002). The superimposition of this map with morphological units and vegetation unit led to the identification of the management units. The management plan is also designed in order to cope with invasive plant, in particular *Ailanthus altissima* and *Robinia pseudoacacia*, species that usually are fostered by clear cut aimed only at reducing the flood risk.

A discussion of the implementation of the management plan is made possible by the execution of some first vegetation cuts and by a major flood that led to significant evolution of the active channel.

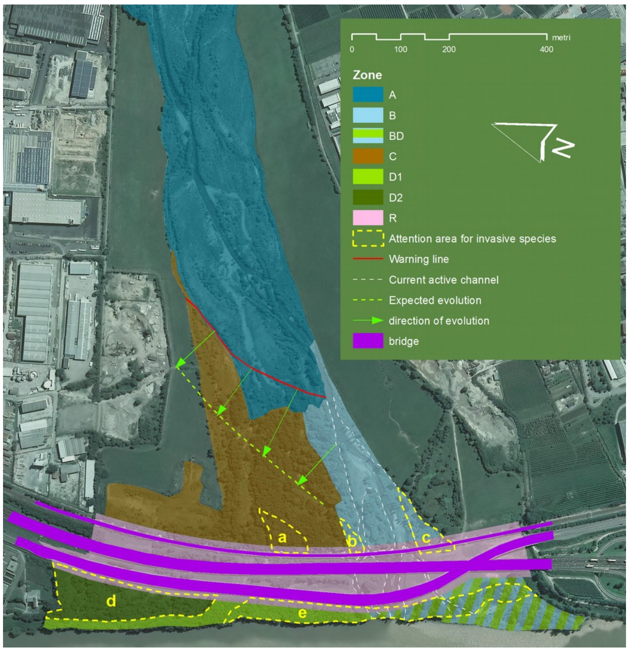

Figure 4: Zonation of river corridor.

Acknowledgments

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Retention and stability of driftwood in a wood restored lowland stream.

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Abstract

Restoration with wood usually concentrates on the installation of stable and massive structures, while there is often a lack of ecologically important small pieces of wood. To compensate for this deficit, the retention of driftwood at wooden installations is of interest. We investigated the retention and stability of driftwood in a lowland stream reach four years after restoration with stable wood installations compared to an unrestored reach as a control. The wood standing stock was assessed and the dynamics of tagged wooden elements observed. Transport distance and stability of standardized pieces of driftwood were assessed in field experiments. Retention of driftwood at wooden installations increased the wood standing stock by 11 % in volume, 29 % in surface area and 49 % in the number of pieces. Unfixed wood was dynamic and most of it was replaced within one year. Stable wood installations in the main current emerging from the water surface at high flow were most effective at retaining driftwood. The reach with wood installations retained more driftwood and driftwood stability was increased at high flow compared to the unrestored reach. Channel-spanning jams did not occur and wood retention caused minor to no afflux. Hence, we recommend retention of driftwood providing ecological benefits as an important objective when restoring lowland streams with stable wood installations.

Keywords: *wood dynamics, driftwood, restoration, lowland stream, invertebrates.*

Introduction

The installation of wood structures in stream restoration is mostly carried out using coarse wood (diameter > 0.1 m). Thus, the wood in restored reaches deviates in composition from the natural, which is particularly characterized in low energy streams by a large quantity of small pieces of wood from the canopy of the riparian trees. Since small pieces of wood are particularly valuable to many aspects of stream ecology (Wallace et al. 1999), it is relevant if large wood installations can retain small pieces of driftwood. However, wood installations, at least in cultural landscapes, are often designed to avoid the assembly of channel-spanning wood jams. We investigated the dynamics and retention of driftwood in a wood-restored and an unrestored reach of a lowland stream. We wanted to assess if large wood structures affect the retention and stability of smaller pieces of driftwood, even though the former were designed to avoid the formation of jams.

Study Area

The Ruhlander Schwarzwasser stream is a sand dominated lowland stream, with a mean slope of 0.8 ‰, situated in Brandenburg, Germany. The stream is incised due to straightening, drainage of ground-water from lignite mining and regular removal of coarse woody debris until 1992. The mean discharge is 0.6 m³/s, the width 5.5 m and the water depth at base-flow is 0.4 – 0.5 m. About 60 % of the banks are covered by riparian forest, dominated by alder (*Alnus glutinosa*) and oak (*Quercus robur*), providing driftwood from the canopy. A length of 400 m of the stream was restored in 2007 by installing 18 stable wood structures that ranged in blockage ratio of the cross-sectional profile at mean discharge from 25 – 75 %. A comparable unrestored 400 m reach situated 300 m downstream served as a control reach.

Materials and Methods

All pieces of wood longer than 0.5 m and above 0.01 m in diameter were mapped in 2011, four years after restoration. We recorded the length, diameter, buoyant or sinking state, position in relation to flow, proportion submerged and proportion buried in sediment.

In addition to the survey, we traced driftwood retention and stability experimentally. A hundred, respectively 81, pieces of driftwood were successively released at the upstream ends of the restored and the control reach at summer base-flow and winter high-flow (almost bank-full). The pieces were 1.38 m long, corresponding to the mean length of the in-stream wood. Each piece of driftwood was individually traced until it was retained or floated beyond the reaches. Pieces retained in the reaches were removed so they could not affect the retention of any following pieces of driftwood. A second release was conducted with 75 tagged pieces of driftwood per reach at a flow between base-flow and mean discharge to estimate the mid-term stability of the wood retained. All pieces of wood retained in this experiment were left in the stream and their position was mapped for eight weeks at two-week intervals.

Macroinvertebrates were sampled on the driftwood and the dominating bed substrate sand in an area of 0.18 m² each to evaluate the ecological effects. Samples were taken in the summer, autumn and spring from 2008 to 2009 and pooled for the analysis presented in this paper.

Results

The wood standing stock in the control reach was 0.22 m³, 9.7 m² and 65 pieces per 100 m². Disregarding installed wood structures and the associated driftwood pieces the wood standing stock in the restored reach was similar with 0.2 m³, 10 m² and 77 pieces per 100 m². The installation of wood structures increased the standing stock by 300 % in volume to 0.8 m³/100m², 71 % in surface area to 17.1 m²/100 m² and 1 % in the number of pieces to 78 pieces/100 m². The driftwood that was directly associated with the installed wood structures further increased the wood standing stock by 11 % in volume to 0.89 m³/100 m², 29 % in surface area to 22.1 m²/100 m², and 49 % in the number of pieces to 116 pieces/100 m². As expected, wood structures that emerged from the water surface at mean discharge retained more driftwood than submerged wood structures (Mann-Whitney U test; $p = 0.001$). Retention efficiency was also clearly higher for wood structures positioned in the main current. Channel-spanning jams did not occur and retention of the pieces of wood had minor to no influence on the blockage ratio of the wood structures and, hence, the water level afflux, especially at high flow.

Pieces of wood that were not technically fixed were highly dynamic. An amount of 67.1 % of pieces of wood that were mapped and tagged in a pre-survey in 2010 ($N = 359$) had been exported from the restored reach within one year: 23.4 % had been relocated downstream within the reach, while only 9.5 % had not moved at all. Hence, most of the driftwood standing stock was imported within this year. Wood that remained in the reach had a mean length of 1.9 m and was 0.37 m longer than wood that was exported from the reach (Mann-Whitney U test; $p > 0.001$). The stability of the tagged wood was not related to buoyancy, the position in relation to the flow, or to the submerged or buried part of a piece of wood.

The effect of the installed wood structures in the experiments on driftwood retention was related to discharge. At base-flow, the retention was similar between the restored and the control reach and all the pieces of driftwood were retained within the reaches ($N = 104$ and 99, respectively). The mean transport distances were 83 m and 82 m, respectively (15 – 320 m). When the water flow was nearly bank-full, a lower number of driftwood pieces was retained in both reaches, with 70 % (57 out of 81) in the restored and 41 % (33 out of 81) in the control reach. The mean transport distances, calculated from the pieces retained, were 123 m (5 – 370 m) in the restored and 165 m (45 – 340) in the control reach. The number of contacts between a drifting piece of wood and the stable wood installations or the bank was 40 % higher in the restored reach with 3.1 contacts/100 m compared to the control with 1.8 contacts/100 m (Mann-Whitney U test; $p > 0.01$). Once a piece of wood was retained, its stability was higher in the restored reach. After a period of eight weeks, about 23 % (17 out of 75) of the retained pieces of wood was still found in the reach at the wood installations in contrast to only about 1 % in the control reach.

Wood is a valuable habitat for invertebrates. The abundance and number of macroinvertebrate taxa was 2.5 times higher on the wood compared to the dominant substrate sand, with 75 and 30 ind/m² and 42 and 17 taxa, respectively. The abundance and number of EPT taxa on the wood exceeded those on the sand by a factor of 10 and 7 with 20 and 2 ind/m² and 21 and 3 taxa, respectively.

Discussion and Conclusions

The installed wood structures clearly increased the wood standing stock by retention of smaller pieces of driftwood. This wood improved the habitat for macroinvertebrates, for which small pieces of wood is as effective as large (Lester et al. 2009). The abundance and number of invertebrate taxa on wood and sand confirmed wood as a high quality substrate compared to sand (e.g. Smock et al. 1989, Johnson et al. 2003).

The mobility of the pieces of wood in the lowland stream was surprisingly high. This is in accordance with findings on the mobility of large pieces of wood in a low gradient headwater stream (e.g. Dixon & Sear 2014). The surprisingly high mobility in our study was probably related to a major flood between the pre-survey and the tagging of wood in 2010 and the survey in 2011. This flood exceeded the mean discharge by a factor of 12.5. However, the replacement by driftwood from upstream was of great importance to maintain the wood standing stock. Due to the high dynamics of the wood, the restored reach presumably did not significantly influence the amount of driftwood in the downstream control reach.

Wood is mainly transported at high flow (e.g. Bilby 1984) and parallel to the direction of flow in the main current (Braudrick & Grant 2001). This matches the highest retention found for installed wood structures emerging from the water surface at high flow in the main current. According to the classification of Manners et al. (2007), only partial jams occurred four years after the installation of the wood structures. The porosity of accumulations in these partial jams was estimated as high and the cross-section blockage ratio of the installed wood structures was not increased significantly, which was also corroborated by the zero to low afflux observed. Hence, the driftwood retention at the constructed wood installations caused only minor changes in the hydraulics of the channel and ecological benefits predominated.

Increasing the potential for the retention, retention time and stability of driftwood is significant for stream management. Wood structures positioned in the main current and emerging from the water surface at high flow are promising measures for these objectives.

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Woody debris in Bavarian torrential hazard analysis

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Abstract

As part of the process of developing a standard for torrential hazard analysis in Bavaria some investigations were conducted in the field of woody debris assessment. A GIS based method was developed especially to assess the volume of woody debris potential and the woody debris transported volume. This method combines expert knowledge with available basic data and is easily adjustable to further knowledge. The GIS tool is part of an overall assessment of the relevance of woody debris.

Keywords: *Woody debris, hazard analysis, torrent control, Bavaria*

Introduction

The law requires that Bavarian water management authorities have to assess hazard zones caused by torrents for the whole alpine area of Bavaria. To face this demand a special development project was initiated. A modern and suitable technical framework or equal standards needed to be elaborated to gain appropriate comparable, reproducible, and high-quality results in hazard analysis. In this context it is of course also necessary to regard woody debris in hazard analysis.

Materials and Methods

The existing approaches to consider woody debris potential or woody debris transported volume are generally based on empirical data (comp. Rimböck et al (2013)). However it is worth mentioning that due to deficits in systematic measurements the quality of available data concerning wood in torrents is very poor. More complex methods mainly rely on field observations, where the specific volumes are estimated or measured. This results in a lot of effort whilst many uncertainties still remain, for example which material starts to move under which conditions and how far the transport will proceed.

Therefore a new approach to assess woody debris in torrents was required. It is expected to achieve only rough results and to require limited effort, using as much existing data as possible.

The whole assessment process is structured into three phases;

a) Preparation: is woody debris relevant in this case?
b) Assessment of woody debris volume
c) Evaluation of the volume and if necessary consideration in hydraulic calculation

For the main phase b) a method based on an assessment of source areas for woody debris that differentiates between relevant input processes such as landslide, bank erosion, windfall, … was considered as most suitable to fulfil the demands.

Results

The main content of the preparation phase (a) is a "guided expert assessment". This consists of several leading questions, where the experience and event documentation is also taken into account. The main aspects are to assess if on the one hand relevant woody debris transport has to be expected and on the other hand a danger of clogging a narrow torrent section exists. So if there is no narrow section or a bridge is well constructed and the danger is insignificant, the assessment process is already completed.

For the second phase (b) a new method, based on former works (comp. Rimböck (2001)) and on data in geographical information systems was developed. Figure 1 shows the basic principles of this method. One criterion was to gain reliable results within a short time. Of course, due to the lack of data and the remaining lack of detailed knowledge about mobilization processes (e.g. which single log mobilizes under which conditions and which interactions to other logs will occur?) many steps still require expert assessment. For details see Meyer, J.; Rimböck, A. (2014).

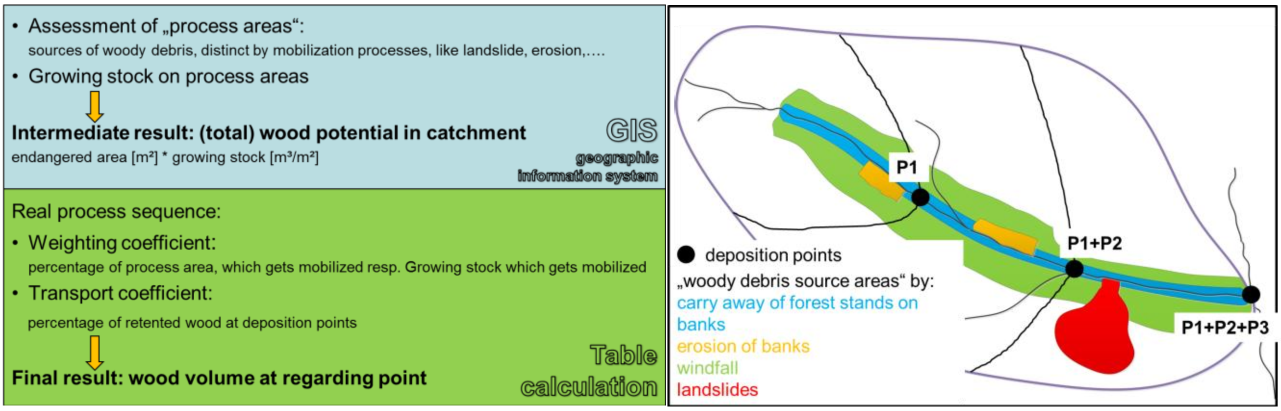

Figure 1: structure of assessment process for woody debris volume in Bavaria

If this assessment shows significant wood volumes, it is recommended to verify this by e.g. field observations. Then this, in turn, has to be taken into consideration in the hydraulic calculation to investigate the torrential hazard areas (phase c). In this phase logging scenarios at the relevant cross sections will be regarded, based on physical experiments by Gschnitzer et al (2014).

Discussions and Conclusions

In the elaborated concept expert assessment still plays a significant role. For this we have achieved some progress, moving from an overall and general estimation towards a focused and target-oriented estimation. Especially the coefficients for process areas and the transport process are largely based on estimations, where experience is vital.

The concept can be characterized as modular: on the one hand, it allows a step by step assessment whereby the necessity of the following step is dependent on the result of the previous one. On the other hand, in several stages, additional knowledge or data can be easily incorporated if and when it becomes available. This especially affects the coefficients – they can easily be changed on the basis of observed data.

Even regarding the still remaining uncertainties the method marks a significant improvement, as it gives a good overview over the whole catchment area and points out the most important sources for woody debris. This also facilitates field observations, as the time consuming work can be focused on these areas. Furthermore, performing scenario tests with the coefficients can result in a better understanding of the significant processes and interactions.

Of course in many fields regarding woody debris in torrential hazard analysis the need for more research and development remains. This is mainly related to aspects of mobilization, retention and deposition processes. This is strongly dependent on the development within the catchment area, such as sequence of flood events and processes in the periods between floods. It was observed that the amount of transported woody debris is much higher if more events have occurred within a short time. The reason for this is that mobilization processes, such as erosion of banks, may have begun in the first event but only resulted in wood transport in the late phase of the event. In a following event those processes and actual wood transport start to occur at the beginning of the event and last during the whole event. As a consequence, much more volume is mobilized and transported in a subsequent event. Such interrelationships are difficult to integrate in to the assessment process.

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Bridge clogging caused by woody debris: experimental analysis on the effect of pier shape

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Abstract

The accumulation and blockage of woody debris (WD) at bridges is a relevant problem in flood hazard management. Blockage may cause a strong reduction in the flow rate through the contracted opening and therefore a strong increase in upstream water levels which may lead to flooding or nearby urbanized areas.

Physical scale model tests on bridge clogging were conducted in the hydraulic laboratory of the University of Florence.

We reproduced three different pier shapes (semi-circular nose, triangular nose and a cutwater of streamlined shape formed of two arches of circles) and four constriction geometries (with and without pier in the channel). Driftwood elements were reproduced using wooden cylindrical dowels of three sizes and two types of log transport were reproduced: congested and uncongested.

A dimensionless index quantifying the capability to block the transport of WD was defined and calculated for the various geometrical configurations employed. First results suggest that the triangular nose is more effective in blocking WD.

Keywords: *bridge clogging; woody debris.*

Introduction

The topic of woody jam formation at bridges (both single pier accumulation and span blockage) has encountered a growing interest of the researchers in the last years (e.g. Dihel, 1997; Bezzola et al., 2002; Lange and Bezzola, 2006; Schmocker and Hager, 2011; Lyn et al., 2003). The relevance of this topic is also related to wood maintenance strategies of in-channel and riparian vegetation, correlated to the flood risk management.

Most of the last flood events that occurred in the years and described in the literature (such as the 2005 flood event in Switzerland) were characterized by high and long lasting flood flows, insufficient discharge capacity and blockage of flow cross-sections, enormous amounts of large woody debris entrained, high damage to infrastructures (Gordon et al.,2004; Schmocker et al.,2011).

Flume experiments and studies were carried out on debris accumulation at bridge deck (Schmocker et al., 2011) or at a semi-circular bridge pier (Gschnitzer et al., 2013; Lyn et al., 2003). Very little is known about the influence of pier shape on woody debris entrapment. This aspect is of relevance for historical bridges typically characterized by non-trivial pier shapes (such as the triangular shape of the Old Bridge in Florence, or the two arches of circles shape in the case of the Wilson Bridge in Tours, France).

The aim of the present work is to individuate the pier shapes more prone to developing blockages.

Here, we present a preliminary analysis of bridge clogging caused by different constriction geometries and pier shapes. We considered the simple case of no-rooted logs, steady flow and fixed bed conditions in a low gradient river.

Materials and Methods

The experiments were conducted in a rectangular 5.095 m long and 0.30 m wide flume. The fixed bed had a slope of 0.001 and was covered by uniform gravel (D_{50} = 6.81 mm).

All the experiments were carried out with a constant Froude (Fr = 0.3) and steady flow conditions. The discharge was Q_{model} = 4l/s.

Driftwood elements were reproduced using wooden cylindrical dowels of three sizes (small, medium and large in relation to stream width). The relative size (ratio of dowel size to river cross-section width) and the frequency distribution of the dowels were defined on the basis of field data collected in the Arno river basin (Table 1). The model scale can be considered a 1: 55.

Table 1: geometrical sizes of dowels and logs classes.

WOODY DEBRIS	CLASS	% of presence	Real sizes		Physical model sizes	
			L_{wood} (m)	D (cm)	L_{wood} (cm)	D (mm)
Small	1 (L_{wood}<$L_{channel}$)	**56.6**	5-11	5-10	10	2
Medium	2 (L_{wood}=$L_{channel}$)	**34**	12-16	15-20	17	4
Large	3 (L_{wood}>$L_{channel}$)	**9.4**	17-20	25-35	20	6

Three different pier shapes (semi-circular nose, triangular nose and a cutwater of streamlined shape formed of two arches of circles) and four constriction geometries (with and without pier in the channel) characterized by the same ratio between span width and channel width, were analyzed.

In the experiments, two types of log transport were reproduced: congested and uncongested (Braudrick et al., 1997). The capability to block the transport of WD was quantified by the dimensionless index IAC (blockage index) (Betti et al., 2006) defined as the ratio between the number of captured logs for size class and the total number of logs introduced in the flume for size class.

Results

Figures 1 and 2 show the dimensionless index IAC as a function of wood size classes and for different constrictions geometries and pier shapes, respectively.

The higher values of IAC are obtained for geometries with piers in the middle of the channel (geometries 1 and 4 versus 2 and 3 in Fig.1). In this last case, triangular bridge piers (Fig. 2) is the most critical for woody debris entrapment during transport. The values of IAC for triangular and two-arches shape of piers are similar while the semi-circular shape of pier shows a greater capability of logs to rotate around the nose and to flow away, reducing the blocking probability (Fig.2).

Overall, results show that the IAC increases with logs sizes, the higher values are obtained for large woody debris unlike the small woody debris.

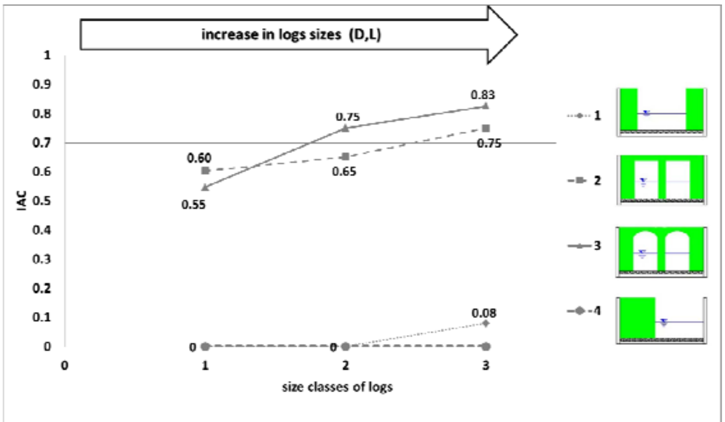

Figure 1: IAC index for different log size classes in the case of 4 different geometrical constrictions.

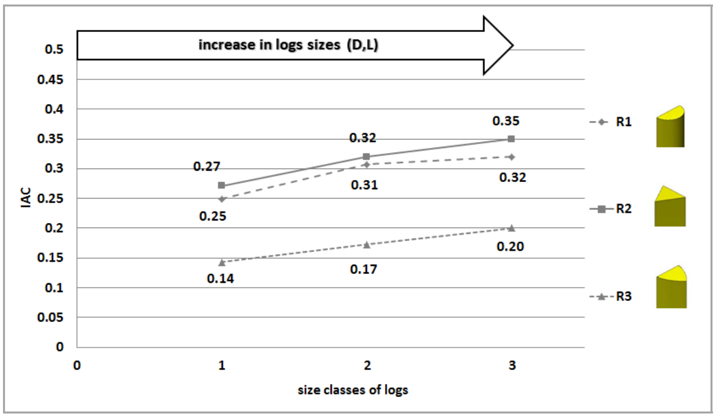

Figure 2: IAC index for different log size classes in the case of 3 different pier shapes.

The logs more prone to be captured are those in class 3 having the smaller frequency (see Table 1).

Discussions and Conclusions

Preliminary results show that the triangular shape of bridge pier is the most critical for the accumulation of wood, and the class of the largest log size is the one more prone to be blocked. This has relevant implications for the evaluation of hydraulic risk at historical bridges with this pier shape (like in the case of 'Ponte Vecchio' in Florence).

It is important to note that the dowels used in our tests represent no-rooted and defoliated logs. The presence of roots and branches could influence the entrapment of woody debris at bridges.

Further tests and flume experiments are needed for different bridge geometries in order to individuate the critical structures for wood debris accumulations.

Acknowledgments

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Riparian vegetation management along the Secchia river (northern Italy)

Experimenting sustainable management practices

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Abstract

The “Interregional Agency for the Po River - AIPo” mission is to protect the Po river plain from flood inundation trough maintenance of hydraulic structures – such as levees – and riverbeds where the riparian vegetation, especially in the last decades, has developed not always compatibly with flood safety standards.

Past management practices on riparian vegetation, based only on minimizing hydraulic roughness, are inadequate. The riparian zone has, in fact, a multifunctional purpose in stabilizing the banks, in reducing the risk of flooding slowing down the flood, and in being a landscape and recreational element for the environment.

Basing on these assumptions, AIPo is testing more adequate techniques to manage riparian vegetation which involve: (1) hydraulic modelling and knowledge of the riparian habitat, (2) sharing with stakeholders, (3) best practices for wood-energy operators and companies and (4) monitoring the results of the planned actions.

This model of intervention, based on the Rhone-Mediterranean and Corsica Water Agency SDAGE guidelines, and shared with a complex mosaic of stakeholders, is currently being tested, on the Secchia river, a right tributary to the Po River which flows northwards across the Apennine Mountains, mostly in Emilia-Romagna Region, and, in its final stretch, in Lombardia.

Keywords: riparian management, hazards, fluvial ecosystems, objective sharing, economic sustainability.

Introduction

The Interregional Agency for the Po River (AIPo, the Italian acronym), is a public body that provides engineering and environmental services across the full spectrum of operations in support of interests of the Italian regions crossed by the Po river: Piemonte, Lombardia, Emilia – Romagna and Veneto. Its mission is to provide flood protection and flood damage reduction. The Agency operates through its main Headquarter in Parma, 12 divisions throughout the River Po Basin and a Research and Development District. It was established in 2003 and took over the role of the previous organization called "Magistrato per il Po", which was part of the Ministry of Public Works.

In the past “Magistrato per il Po” ensured the safety of rivers, providing for clear felling practices of riparian vegetation in the riverbed, with close interventions to ensure the minimum hydraulic roughness of the riverbed and a rapid transit of floods.

Over the past 20 years, the decrease of the economic resources for maintenance works of hydraulic structures and riverbeds, and the acquired awareness of the environmental value of riparian forests have triggered a conflict between vegetation, meanwhile grown out of control, and hydraulic safety. This conflict is greater on the stretches of man-made fluvial ecosystem, forced into high embankments, hanging on the ground level.

In order to overcome what represents not only an hydraulic safety problem but also an ideological conflict, AIPo recently promoted, on the river Secchia plain, two case studies of riparian vegetation management using the "participatory planning".

Study Area

The pilot area of intervention is the river Secchia, extending for 90 km from the barrage of the "overflow basin to retain its flood waters" and the confluence with the Po river, crossing two Regions (Emilia-Romagna and Lombardia), two Provinces (Modena and Mantova) and a Park of local interest (PLIS) which comprises the floodplains adjacent the river Secchia up to the confluence of the river Po.

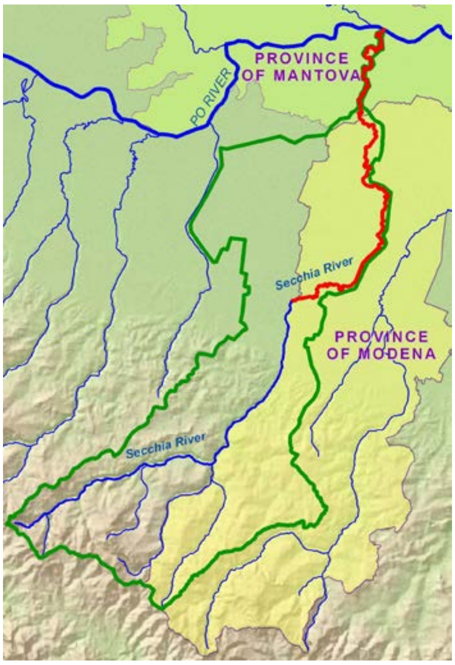

Figure 3: Secchia river basin (green) and area of intervention (red)

Methods of study and intervention

Riparian vegetation management programs in the Secchia river pilot area developed from two initiatives carried on by different requirements but with the same target by AIPo, that is the management of:

- stumps and logs of mature and heavy trees, with superficial roots, grown over steep bank slopes, which can start banks landslides and damages to the levees when very close to the channel (i.e. without overbanks);
- narrow cross sections, bridges with reduced span between piers and, in general, hydraulic works reducing channel width, may be severely damaged by floating logs. Temporary wood dams can easily grow and cause local inundations or hydraulic load at levees or other flood protection structures;
- river stretches with levees height not compliant with the design of river basin authorities for flood protection. Here, the presence of dense and non flexible vegetation increases channel roughness, leading to local flow velocity reduction and consequent higher water depths.

The first one, in the Modena Province territory, developed from the need to plan, under severe pressure of time, the cutting of riparian vegetation provided by the civil protection authority, after the inundation caused by the collapse of the embankment of the river Secchia that occurred on January 2014. The last extensive interventions of river vegetation cutting in the Province of Modena date back to the early 2000s (Anselmo & Terzuolo, 2001).

In only three months, AIPo has achieved, and shared with public stakeholders (National Po river Authority, Emilia-Romagna Region, Province of Modena, Municipalities and Park Authority), a "Program for the management of riparian vegetation", using the methodology proposed by the guidelines of the SDAGE Rhone-Mediterranean and Corsica Water Agency (Agence de l'eau RM & C, 1998). The program is based on:

1) detailed survey of riparian vegetation, 2) hydraulic modelling, 3) definition of management objectives, 4) definition of intensity levels of intervention and 5) definition of criteria for intervention.

The management objectives were based on the identification of different reaches of the river with homogeneous characteristics from the point of view of the hydraulic and morphological requirements, the bank protection from erosion, the reduction of the risk of flooding slowing or fastening the flood downstream. From the result of these studies, intersected with the ecological, functional, typological and structural characteristics of vegetation that descends from the detailed survey, it was possible to define the level of intensity of maintenance and the consequent intervention criteria.

AIPo is now implementing the Program: 26 km of interventions along the Secchia river bed have been designed and contracted for an amount of 1M euros. On the remaining 18 km, where the program provides an intensive level of maintenance, that means that the 70% of vegetation will be cutted, the interventions have been contracted at “zero-costs” to qualified companies operating in the wood energy supply chain.

The second initiative concerning riparian vegetation management, developed in the Province of Mantova starting from 2012, to ensure the hydraulic safety and flood protection of the Secchia river, in a stretch strongly conditioned by environmental protection laws, for the presence of the “Park of floodplains of the mouth Secchia (PLIS)”.

After two year of work with the stakeholders, AIPo subscribed, in April 2014, an agreement with the PLIS, the Lombardia Region, the Province of Mantova, four Municipalities, two Land reclamation and drainage authorities, in order to develop a "*Program for the management of riparian vegetation*", using the methodology of the SDAGE guidelines. The program co-financed by AIPo, the Province of Mantova, the PLIS Park and private companies.

Results

The riparian vegetation management experience carried out in the river Secchia, supported by the SDAGE French guidelines, can be considered a pilot study area, to be replicated in other river of the Po basin, both for technical/scientific methods of intervention and for the positive sharing with public and private stakeholders.

Discussions and Conclusions

The effort for the future is the implementation of a system for monitoring the effectiveness of interventions in order to achieve the objectives of hydraulic safety and sustainable maintenance of riparian vegetation in the Secchia river, including the use of hydraulic modeling and multi-temporal sampling of transects .

The monitoring will allow to establish the frequency and best practices for cutting vegetation in order ensure the compatibility of riparian vegetation with the objectives of the program, and to quantify the resources necessary for the proper management of the river.

On these issues it will be useful to develop discussion and cooperation between the world of research and public administrations.

Acknowledgments

We would like to express our gratitude to Eng. Luigi Fortunato (Director of AIPo from 2008 to 2014).

Thanks to public authorities which worked on the river Secchia riparian vegetation program: Po river Autority, Lombardia and Emilia-Romagna Regions, Mantova and Modena Provinces, local Municipalities, Land reclamation and drainage authorities, River Secchia oriented reserve, Secchia's PLIS.

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PROTECTION FORESTS AGAINST DEBRIS FLOW:

FIELD OBSERVATIONS IN MOUNTAIN FANS

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Abstract

Field surveys were conducted on two alpine fans and highlighted the different role of the forest stand involved by debris-flow events. The decrease of the mortality and the increase of the deposit thicknesses were observed with the increase of the tree diameter. In case of muddy debris flow, trees with diameters greater than 0.25 m showed better chances of survival. The presence of woody debris provided additional protection through the establishment of log steps contributing to the deposition of important sediment amounts. In conclusion, trees and woody debris could offer a natural protection and an additional control 'structure' in delicate areas, preserving the natural landscape or reducing the impact of artificial man-made works.

Keywords: *protection forest; debris flow; damage to the forest; suppression of debris flow.*

Introduction

The forest can offer protection against gravity-driven natural hazards (debris flow/flood, rock avalanche, rock fall, snow avalanche, shallow landslide). Forests reduce the potential for debris-flow-triggering landslides (Schmidt *et al*. 2001; Roering *et al*. 2003), induce the suppression, and promote the deposition of debris flow and other massive phenomena. The possibility of preserving natural environments and landscapes through the active management of protection forests needs to better understand the interaction between flow and trees. The maximum lengths of debris-flow deposition (runout distances) are strongly affected by the rheological properties. Furthermore, the tree presence on the terrain adds topographical roughness, which hinders the flow motion. Despite these, there are relatively few studies of protection forests against debris-flow in transitional and depositional areas (Lancaster *et al*., 1999). May (2002) observed that debris flows passing through mature forests tend to have fewer and smaller landslides and shorter travel distances. The forest ability to suppress the 'flows' depends on tree diameter, forest zone width, and tree density, but these variables are not yet fully defined in the management criteria of protection forests, particularly against debris avalanches and debris flows (Ishikawa *et al*., 2003). This research shows the results of field observations on the damage suffered by the trees due to the interaction with two real debris flows and verifies the link between trunk diameters and thicknesses of deposited sediments. Some key criteria of protection forest management emerge from the investigation.

Study areas, materials, and methods

The study areas are two mountain fans belonging to small catchments in the northeast Italy, where debris-flow events occurred in summer 2012. The first fan is crossed by the Somprade creek (Ansiei valley, Belluno) and it was flooded by a granular debris flow (Ancey, 2001) generated by the rainfall of July 30th 2012. The catchment area is 0.38 km^2 and it extends from 2587 m a.s.l. to 1181 m a.s.l. (fan apex) with an average basin gradient of 1.31 m/m (52.6°). The valley lies in Mesalpic climate districts, where fir forest (*Abies alba*) and spruce forest (*Picea abies*) are typical formations. The second area is the fan of the Hoferlahn creek (Pfitsch Valley, Bolzano). Here, a muddy debris flow occurred due to the rainstorm of August 4th 2012. The catchment area covers 1.12 km^2 and it extends from 2380 m a.s.l. to 1057 m a.s.l. (fan apex) with an average gradient of 0.54 m/m (28.4°). The valley lies in the transition Endalpic district, where spruce (*Picea abies*) dominates.

Field surveys were carried out in each fan in order to map the sediment deposit and to sample the all flood-involved trees, also evaluating their level of damage. The mapping of the deposits was obtained walking along the perimeter and recording significant GPS points. Measurements on the average thickness of deposition were also taken along the perimeter and in some inside control points. The following informations were obtained for each tree: diameter at breast height (*DBH*); vegetative state (dead or alive); species; type of damage (e.g. presence of scar; degree of tip; topping, cutting off, or uprooting); upstream deposit thickness. In addition, three sample plots were selected outside, but near the depositional areas, to carry out a forest inventory in order to compare the 'undisturbed' forest stand with the 'disturbed forest' stand.

Main results

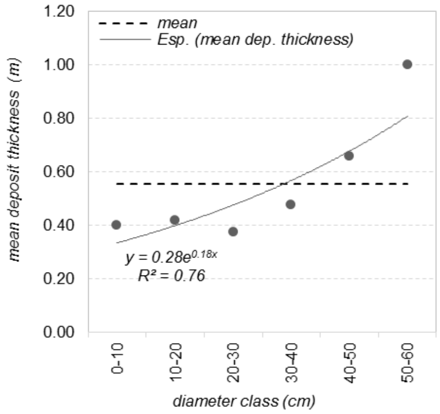
The estimation of the sediment volumes (total event deposit on the fan) was conducted in GIS environment applying the Thiessen polygon method to the detected points, resulted in about 15000 m^3 and 9400 m^3 for the Somprade creek and the Hoferlahn creek. 1044 and 522 trees were surveyed in the depositional area of the Somprade and Hoferlahn creeks, respectively, and 253 and 65 trees were gauged in the undisturbed areas correspondently. The number of trees per hectare (n), the basal area per hectare (A_{bas}) and the mean *DBH* (DBH_m) show significant differences between the greater values measured in undisturbed area and remarkably lower values of the disturbed area, in particular in the Somprade-creek case study (Table 1).

Table 1: Main forest-stand characteristics surveyed in the disturbed areas and in not disturbed area in the two study sites.

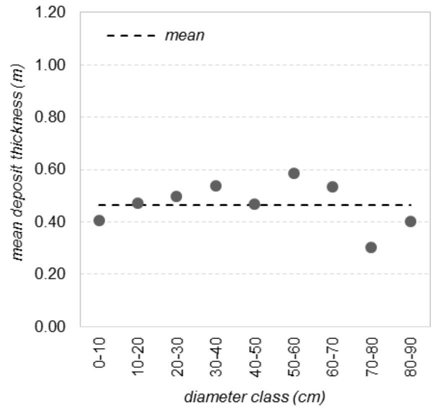
	Somprade-creek event (Belluno)		*Hoferlahn-creek event (Bolzano)*	
	undisturbed area	*disturbed area*	*undisturbed area*	*disturbed area*
n species (-)	6	10	5	11
n *(ha^{-1})*	1974	522	690	466
A_{bas} *(m^2 ha^{-1})*	50.78	24.28	37.27	32.84
DBH_m *(m)*	0.15	0.13	0.26	0.09

In both areas, imbricated boulders shaped depositional forms when piling up against trees. In the Hoferlahn-creek fan, a mature high forest in the upper part and a recolonization formation of pasture in the terminal parts were detected. Here, transported woody debris (*WD*) were observed in particular at the begging of the deposition zone. Often, *WD* originated log steps as result of the flow impact against two or more trees and mutual effect of tree density and transported logs. These local obstructions contributed to the deposition of a lot of coarse debris before its arrival in the downstream fan area, which was occupied by trees with smaller diameters. The forest formation of the Somprade-creek event was that typical of the disturbed zones (many species with small diameters, and high density). The debris flow caused the death of all the trees in the zone of its initial slowdown, being the blocked debris coarser. Moving downstream, smaller sediment sizes and lower impact forces, due to the gradient change, were important factors for reducing of the debris-flow motion. The analysis of the frequency distribution of the tree diameters by classes provided useful information about the forest stands. In the disturbed area of Somprade creek, a residual forest stand with few trees having from medium to large diameters in regeneration was detected, as well as the presence of an established regeneration in the undisturbed area. In the Hoferlahn-creek fan, the disturbed forest stand had an even-age structure with a layer in regeneration, while the undisturbed forest stand showed a selection structure with a large presence of pioneer trees in the classes of the smaller diameters. The trees damaged by the granular debris flow showed an exponential relationship between tree diameter class and deposit thickness (Fig.1.a; mean thickness of 0.56 m). This circumstance did not occur for the trees, which were hit by the muddy debris flow, showing a more uniform deposition height behind the trunks (Fig.1.b; mean thickness of 0.47 m). In the

Somprade-creek area, many died-trees were observed resulting from the impact force of the flow. The mortality within the diameter classes decreases as tree size increases following a lognormal function. In the Hoferlahn-creek area, many inclined trees were found and proved that diameters greater than 0.25 m have high survival probability in case of muddy debris flow.



a) Somprade-creek event (Belluno)



b) Hoferlahn-creek event (Bolzano)

Figure 1: Field data: tree diameter classes (10 cm) versus mean deposition thickness.

Final remarks

After-event surveys resulted in a primary importance to assess the behavior of forest stand against two different types of debris-flow (granular and muddy). The most evident effects can be summarized as follows:

i) The high deposit thickness against the trees involved by the process confirms that forest buffers in the fan area can offer an effective protection by hindering the flow mobility. The maximum boulder diameters blocked by trees were in the class of 50-60 cm for the granular debris-flow and 80-90 cm for the muddy debris-flow.

ii) As to the forest behavior, the main difference between muddy and granular debris-flow consists of promoting a more uniform sediment retaining - regardless the trunk diameters - for muddy debris flow, and a selective effect in terms of sediment thickness - directly proportional to the *DBH* - for granular debris flow.

iii) The optimum management of forest fan area against debris flow should promote low tree density and large trunk diameter (>0.25 m) at the fan apex (high forest) followed by a dense and wide (crosswise the direction of the main stream) forest stand having medium/small diameters of the stems (coppice).

iv) The protective role played by *WD* in dissipating the flow energy and enhancing the debris-flow slow down.

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Controlled scour process due to debris accumulation at bridge piers

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Abstract

Scour process at bridge piers is a very important topic for hydraulic engineers. In particular, it has to be deeply analyzed in order to avoid piers collapse. In the last decades, the scour process has been investigated by several researches. Mostly, studies focused on the prediction of the maximum scour depth and the evolution of the scour hole morphology. Furthermore, the scour process evolution received a particular attention as the comprehension of the physics of the phenomenon during the time is of fundamental importance to develop strategies oriented to control the scour geometry. Nevertheless, the analysis of the scour process cannot be limited to a configuration in which only an isolated bridge pier is present. Logs and wood transported by the flow can create obstacles in correspondence with the piers contributing to deeply modify the scour dynamic and resulting in an increase of the maximum scour depth.

This paper aims to synthetize the dynamic of the scour process in the presence of a bridge pier and debris accumulation highlighting the similitudes and differences in terms of both equilibrium scour morphologies and scour process evolution for different configurations and hydraulic conditions.

Keywords: *Bridge piers; debris; morphology; scour control.*

Introduction

Scour at bridge piers is a topic which have received a great attention from hydraulic engineers in the last decades. Many studies focused on the effect of hydraulic, geometric and granulometric parameters on the maximum equilibrium scour depth both in presence and absence of countermeasures located in the basin in correspondence with an isolated bridge pier (among others Shen et al., 1969, Melville and Sutherland, 1988, Raikar and Dey, 2008, Tang et al., 2010, Masjedi et al., 2010). In addition, the temporal evolution of the scour morphology constitutes another important aspect which was deeply analyzed as the understanding of the scour process dynamic can furnish essential information on the physics of the phenomenon. But for practical applications, it is also important to take into consideration the presence of debris accumulation (such as logs and wood transported by the flow, see Figure 1) in correspondence with the piers, as it strongly affects the scour characteristics and contributes to vary flow conditions (Melville and Dongol, 1992, Parola et al., 1998, Zevenbergen et al., 2006). In this perspective, countermeasures assume a more relevant role, as they can be successfully used to control and reduce scour hole characteristics. Very recently, different countermeasure methodologies were tested by Pagliara et al. (2010) and by Pagliara et al. (2014). Based on the findings of Pagliara and Carnacina (2010) and Pagliara and Carnacina (2011a-b), both Pagliara et al. (2010) and Pagliara et al. (2014) analyzed the effect of sills and gabions (Figure 2) and macro-roughness elements (Figure 3) on scour process in the presence of a bridge pier and debris accumulation. They showed that these two countermeasures are effective in reducing scour geometry if opportunely located. In the following, a brief discussion is reported, regarding the comparison between scour process due to an isolated bridge pier in the presence of debris accumulation (including wood debris) with and without countermeasures located downstream of it. The analysis put in evidence that the scour evolution is strongly depending on the tested conditions.

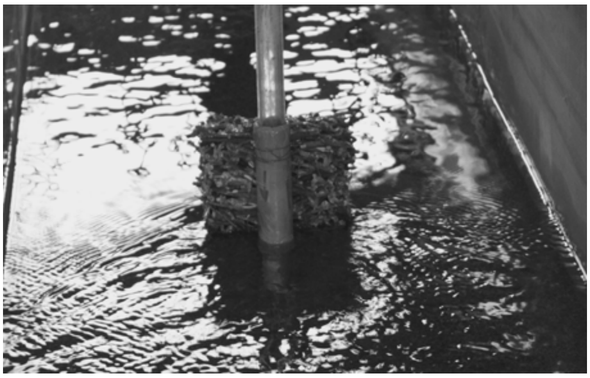

Figure 1: Bridge pier with wood debris accumulation

Figure 2: Scour at bridge pier with debris accumulation and control sill

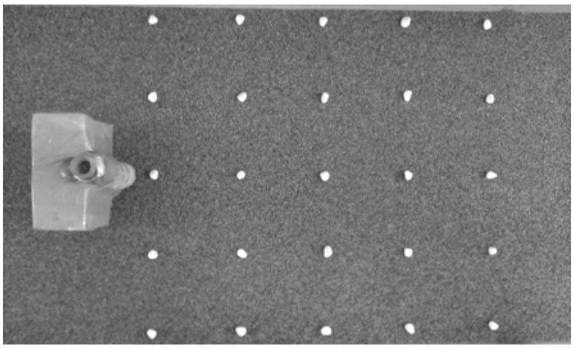

Figure 3: Bridge pier with debris accumulation and downstream macro-roughness elements

Discussions and Conclusions

The presence of debris accumulation deeply modifies the scour mechanism. In particular, experimental tests showed that the scour evolution is mainly depending on the debris geometry. Namely, the longitudinal extension of the scour hole is deeply influenced by the length of the debris accumulation. This aspect is particularly important as it has to be taken in serious consideration in order to locate properly eventual countermeasures. This is mostly due to a significant variation of the flow velocity profiles in correspondence with the pier in the presence of a debris accumulation. In general, the presence of the debris contributes to increase the scour kinetic, i.e., the scour evolution becomes faster. In addition, the increase of longitudinal velocities below the debris causes a decrease of the downstream ridge height, resulting in a longer and deeper scour hole.

Therefore, it appears evident that, especially in the presence of debris accumulation, the role of an eventual countermeasure is fundamental. In particular, if sills and gabion are adopted as countermeasures, the scour dynamic changes significantly. Namely, initially the effect of countermeasure in delaying scour evolution is significant. Nevertheless, once the sill or the gabion get exposed, their efficiency drastically reduces.

The use of macro-roughness elements as countermeasure causes an increase of the stability of the base material. In particular, they cause an increase of the total flow resistance resulting in a reduction of the shear stresses acting on the bed material. Furthermore, they delay the dune migration. This is a fundamental aspect to be taken into consideration, as the dune plays a fundamental role in limiting the scour hole evolution. In other words, the dune confines the scour hole and limits both its planar extension and its maximum scour depth. Therefore, the scour hole evolution becomes slower. Finally, this countermeasure appears very efficient in terms of scour volume reduction.

In conclusion, especially in the presence of debris accumulation, the experimental observations showed that macro-roughness elements can be considered the most efficient countermeasure among those tested as, at the same time, they are effective and very economic.

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Integrated use of remote sensing and geographic information systems in riparian vegetation and check dams monitoring in the Carapelle watershed (Northern Apulia, Southern Italy)

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Abstract

Riparian vegetation is an important part of river ecosystems. It is able to provide many important functions for protecting land, water and natural habitats in catchments. In the context of watershed management, assessing the effects of torrent control works on riparian vegetation is important. In this work, the study area is the Carapelle watershed (Northern Apulia, Southern Italy), a typical Mediterranean semi-arid area. Firstly, a detailed geographical database, derived from a survey of all existing check dams in the watershed, was created in order to obtain information about each check-dam (geographical coordinates, material, conservation, efficiency) and related vegetation (species composition, density). Then, the distribution of riparian vegetation at the watershed level was derived from the land use map of Apulia region, corrected by means of visual ortophoto interpretation. Vegetation indices (NDVI and LAI), calculated by processing a multi-seasonal Landsat 8 image series (period 2013-2014), were used to create LAI distribution maps in the watershed. Finally riparian vegetation along selected segments of streams, with and without check dams, were coupled- compared, in terms of LAI, to assess the relationship between torrent control works and vegetation.

Keywords: check dams; LAI; GIS and Remote sensing; riparian vegetation.

Introduction

Riparian vegetation is recognized as an important part of river ecosystems. It is able to provide a variety of services, including sediment filtering, bank stabilization, water storage and release (Naiman et al., 1993; Tockner et al., 2008). Riparian vegetation can be influenced by natural and anthropogenic disturbances (Masahito and Nakagoshi, 2001; Džubáková et al., 2015). Among these, the torrent control works can play a role. While research on the structure and distribution of riparian vegetation has been considerable (Nilsson et al., 1991), quantitative evaluations of the impact of torrent control works on riparian vegetation are rather limited (Bombino et al., 2006). The assessment of the effects of torrent control works on riparian vegetation is also important for watershed management and planning (National Research Council, 2002; Gentile et al., 2006). In this work, field surveys, geographic information systems (GIS) and remote sensing are combined in order to assess the effects of check dams, placed along some streams in the watershed, on the processes of naturalization and growth of riparian vegetation.

Study Area

The study area is the Carapelle watershed, a Mediterranean medium-size watershed (982,6 km^2) located in Apulia, Southern Italy. The Carapelle torrent is one of the main streams that furrow the Tavoliere Plain, between the Ofanto River and the promontory of Gargano (Figure 1). The watershed areas with low slopes are used for cereal cultivation and olive orchards, while in the high steep slopes deciduous oaks, hardwoods (*Quercus pubescens* W. and *Quercus cerris* L.), and pasture conditions are present. The climate is typically Mediterranean, with rainfalls ranging from 450 to 800 mm·year^{-1} and average temperatures from 10 to 16°C.

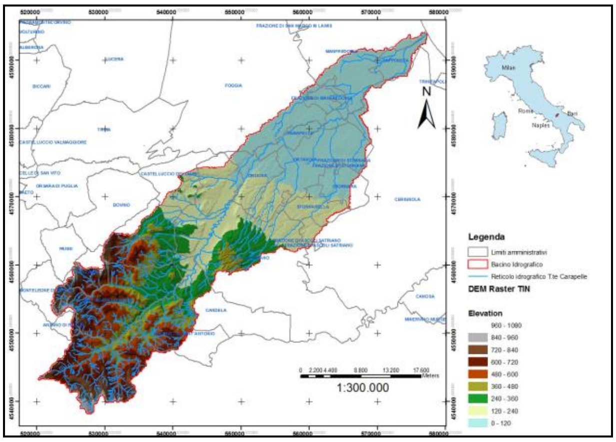

Figure 1 – The Carapelle watershed

Materials and Methods

A survey of all existing check dams in the watershed (Gentile et al., 2006), was used to create a detailed geographical database. Every information about each check-dam (geographical coordinates, material, conservation, efficiency) and related vegetation (species composition, density) were included in the database. The land use map of Apulia region was used to obtain the distribution of riparian vegetation at the watershed level. Due to uncertainties that emerged from the analysis of the land use map, a detailed check was made by means of visual ortophotos interpretation. Vegetation indices (NDVI and LAI), were then calculated by processing a multi-seasonal Landsat 8 image series (period 2013-2014). Landsat images were chosen for their good characteristics in terms of availability, spatial and temporal covering and resolution if referred to a watershed level. LAI was calculated applying a non-linear NDVI-LAI relationship (Milella et al., 2012) and LAI distribution maps in the watershed were created.

Results

The geographical database consists of 238 check dams in the watershed. About 80% of the entire number of these check dams is still efficient but needs however maintenance. The vegetation has colonized about 80% of the check-dams, with a relative variability of vegetation density located upstream and downstream of the works. As regards the LAI, the results well describe the vegetation types in the area, and are consistent with LAI values obtained in other studies (Trotta, 2007) carried out in similar areas and conditions. Finally the comparison of vegetation indices along selected segments of streams, with and without check dams, show that LAI values are similar in both cases (Figure 2).

Discussion and Conclusions

This study confirms that the integrated use of geographic information systems and remote sensing can be an useful tool in order to monitor and assess riparian vegetation in areas where check dams are present. Moreover Landsat images can be a good compromise, in terms of image resolution and riparian vegetation features, when working at the watershed scale. The results show that the vegetation indices (LAI) are quite similar in segments of streams with and without torrent control works. Further confirmation of these results are needed by means of field surveys, aimed at monitoring the actual conditions of the analyzed segments of streams and measuring the vegetation density on site.

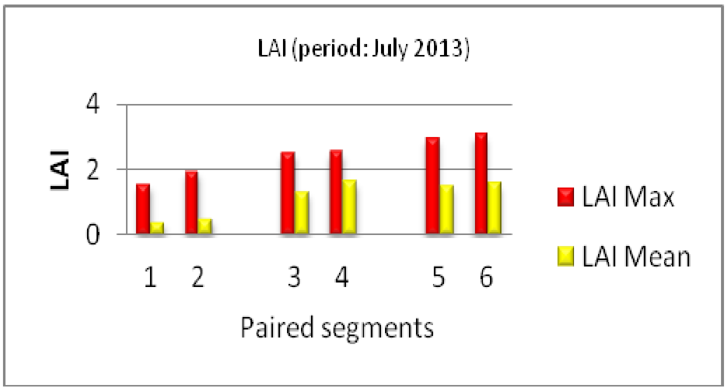

Figure 2 - LAI values of riparian vegetation detected using Landsat images along paired segments of streams with (numbers 1, 3, 5) and without (numbers 2, 4, 6) check dams

Acknowledgments

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Large wood characteristics in native forest and pine plantation streams of the Costal Range of southern Chile

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Abstract

The amount and morphological effects of in-channel large wood depends on the characteristics of riparian vegetation and land use and changes at the basin scale. The present study reports on a comparison among two basin of comparable climate, size, slope and exposition, but featuring native forest and pine plantation cover. Evidence show that the stream draining the native forest basin has more large wood, and even if logs are slightly smaller than in the pine plantation, exert higher morphological influence, developing more and deeper pools.

Keywords: *Land use; Large wood; First-order streams; Chilean Costal Range.*

Introduction

The ecological properties of a stream strongly depend on its morphological pattern and changes. From this point of view, the type and size of riparian vegetation play a crucial role in influencing fluvial style (Hupp & Osterkamp, 1996). The geomorphic effect of living plants continues even after their erosion from the banks or the portion of basin directly connected to the river network, and their transportation within the fluvial network. Dead or living pieces of large wood (hereon LW), can exert a tremendous influence on river erosion and sedimentation processes (Jeffries et al., 2003), channel morphology (Abbe & Montgomery, 2003), and channel hydraulics (e.g. Wallerstein et al., 2001). LW has also been found to play a key role in the ecological diversity of river channels providing habitat for a range of fish and other riverine fauna, and regulating water temperatures, and nutrient fluxes (Van der Nat et al., 2003). Logs can accumulate in logjams, which can modify stream channel hydrology and geomorphology (Wohl & Cadol, 2011), increasing the retention of sediment and organic matter. Logjams create biogeochemical hotspots in headwater streams, increasing stream metabolism and animal production. Also, logjams enhance overbank flooding and sedimentation and can store sediments and form pools. The abundance of wood loads and logjams frequency in mountain streams fluctuate through time due to natural recruitment processes (e.g., wildfire, insect infestation, debris flow,) and human disturbances (e.g., extensive timber clear-cuttings, extensive forest plantations). Streams draining basins impacted by human activities usually exhibit low wood load, which require very long time to return to original levels. The effect of substitution of native forests by exotic forestry plantations on different organisms and ecological processes has been largely studied (e.g. Arevalo & Fernández-Palacios, 2005) mainly reporting reductions in biodiversity within plantations depending on the management and silvicultural methods. In Chile, some studies suggest that native forest replacement by pine plantations modify different abiotic variables and hydrology (Iroumé et al., 2006), and some works specifically focused on LW suggest that wood dimensions, storage and morphological effects vary considerably as a function of forest disturbance history (Comiti et al., 2008; Ulloa et al., 2011). However, more research is needed to understand the complexity of large wood, recruitment and mobilization processes, and the effects on river channel morphology, and ecology in Chilean basins as consequences of replacement of native forest by forestry plantations. This study reports on a comparison between two streams draining basins of similar size but different land use (i.e. native forest *vs.* pine planation).

Study Areas

The study was carried out in two streams located in the Coastal Range of southern Chile, named Cerezos and Arañas (37° 35' 22" S; 73° 14' 54" W). The basins have the same exposition, lies at the same elevation, drain areas of approximately the same size (~ 4 km^2), and are only 5 km apart. However, their land use is fundamentally different, as the Arañas is almost completely covered by evergreen native forest whereas the Cerezos features a dense Pinus radiata plantation.

Materials and Methods

A length of 376 and 822 m was surveyed in the Cerezos y Arañas streams, respectively. The longitudinal profiles were surveyed using a laser distance meter with inclinometer. Overall, 12 and 8 reaches were identified in the Cerezos y Arañas streams, respectively, as being uniform in terms of slope, width and abundance of large wood. Channel variables measured in the field at each single reach include the mean bankfull width, mean fluvial corridor width and mean bankfull depth. The reach-averaged channel slope varies from 0.04 to 0.2 m m^{-1}. All wood pieces greater than 0.10 m in diameter and 1 m in length (see Wohl et al., 2010) were measured in both the active channel and in the adjacent active floodplain using a tape and a tree caliber. The volume of each wood element was calculated from its mid-diameter and length. All visible pieces composing log jams were measured as well.

Results

Figure 1 shows that the basin covered by native forest features more large wood pieces (5900 pieces ha^{-1}; 280 m^3 ha^{-1}) than the basin covered by pine plantation (1710 pieces ha^{-1}; 127 m^3 ha^{-1}). However, it is worth pointing out that nearly half of the whole amount of wood of the native forest stream was found in a single reach hosting a massive valley jam of more than 20 m^3 and featuring at least 470 logs. As to the size of logs, those lying in the native forest (the Arañas) are slightly shorter and smaller than in the pine plantation basin (the Cerezos). Besides, the number of pools per 100 m of channel length is higher in the Arañas than in the Cerezos (16 and 12, respectively). Similarly, the number of jams per 100 m of channel length is higher in the Arañas than in the Cerezos (8.3 and 6.7, respectively).

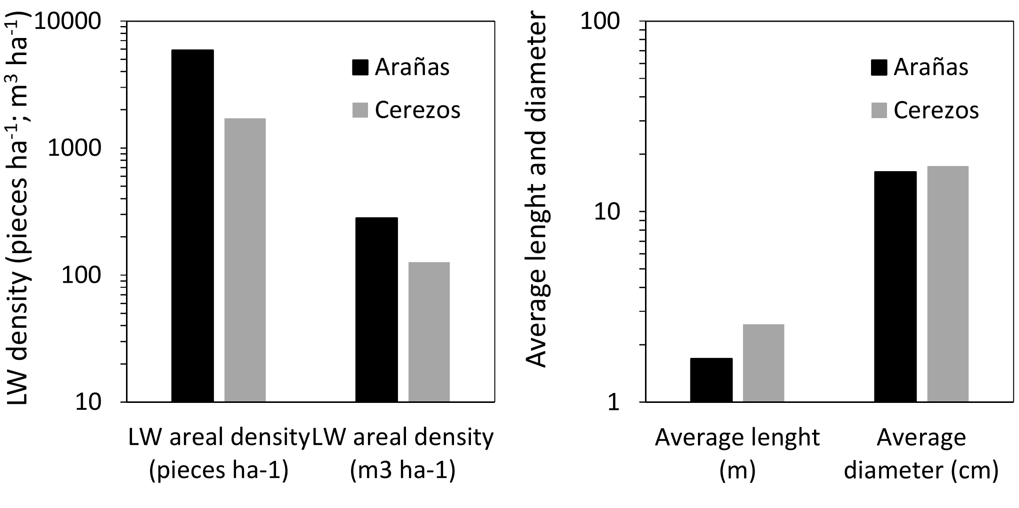

Figure 1: Amount and average size of logs found in the native forest (Arañas) and pine plantation basins (Cerezos).

Discussions and Conclusions

A previous study on the volumes and morphological effects on channel morphology of large wood in the Nelson region of New Zealand (Baillie & Davies, 2002) showed that pine plantation streams contained higher volumes of LW than native forest streams. However, LW in pine plantation had less influence on channel morphology, probably because these pieces had less time to interact with in-channel processes. In the present study, we showed that the native forest stream features more wood than the pine planation. This is partly due to the fact that Pinus wood is less durable than the Nothofagus typical of the local native forest, and likely more related to the fact that the native basin has suffered less LW removal from the channel, and recruited continuously logs of different sizes from bank erosion and basin-related processes (mainly windthrow and landslides). On the contrary, logs reaching the main channel on the pine plantation stream are more homogeneous, and being larger are more immobile. This appears to influence the degree of morphological impacts that can be exerted by wood in the pine planation stream, which is less jammed and produces less and shallower pools. It is worth stressing that large wood in the Cerezos is remarkably higher than in other pine plantation basins surveyed in Chile (e.g. 56 m^3 ha^{-1} in Pichun basin as reported by Ulloa et al., 2011) and New Zealand (average around 120 m^3 ha^{-1} and up to 345 m^3 ha^{-1} y as reported by Baillie & Davies, 2002). This is probably due to the relatively wide buffer of the riparian vegetation left in the Cerezos, and to the history of forest interventions and land uses of each basin.

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Assessment of the protective effects achieved in watersheds with water and forest restorations: application of the Arás torrent basin

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Abstract

With the water and forest restoration (W-F-R) projects in the past, several protection and reforestations works were carried out in the mountain areas in order to avoid or to reduce the natural risks triggered on them. The pass of time has required investments for the maintenance of both the protection works and reforestations. This document set up a methodology using technic-scientific criteria as an approximation to assess the effectiveness of the W-F-R in order to justify the expenses of maintenance of the actions done on the mountains.

Keywords: water and forest; risk; evaluation; methodology.

Introduction

The watersheds in the mountains of the Aragonese Pyrenees were the target of reforestations and torrent correction works (Water and Forest Restorations) within the first half of the XX century to avoid of to reduce the natural risks triggered on them. After a long time since W-F-R were built, it has been demonstrated that overall they achieved satisfactorily their aims. This doesn't discard that in some occasion isolated accidents, or even serious, occurred coinciding with extreme torrential events. But the main contribution of the W-F-R is that they have improved the physical state, the functional behaviour and the landscape of the scenes transformed. But both the works and the reforestations require nowadays investments for their maintenance and conservation. In order to justify those investments a methodology to assess the effectiveness of the W-F-R in the natural risks control in the mountains with technic- scientist criteria is needed. This document deals with this theme with an example: the Arás torrent basin, placed in the town of Biescas.

Study Area

The Arás torrent basin has a surface of 19.25 Km^2 among the catchment area, the gorge and its large alluvial fan of 0.69 Km^2. The highest and lower levels are 2190 masl (Peña Petrus) and 837 masl (draining into the Gállego river). It has a mean slope of 46 % and a round-oval morphology. The main course has two tributaries, Betés torrent on the left and Yosa torrent on the right. Both are very torrential. The mean slope of the Arás torrent is 0.14 $m \cdot m^{-1}$ and their tributaries 0.18 $m \cdot m^{-1}$ and 0.17 $m \cdot m^{-1}$ respectively. Geologically the main formation in the watershed is flysch from the Eocene with alternation of sandstones and marls. But an important part of the basin, overall on the northwest slope, is covered by a mantle with glacial origin. Soil use in the watershed are: 42 % forests, most of it from reforestation; 14 % shrubs with or without trees; 20 % pastures and cultivation; and the rest 24 % mountain pastures or bare rocks.

The main natural risk in this basin is the torrential rises of the Arás torrent, and the most exposed element is the road N-260, which crosses the alluvial fan and goes toward the border with France. At the beginning of the XX century this road was cut every winter due to the torrent events. To solve this problem the first W-F-R project of the basin was executed (1907-12); being broaden with a second project between 1929-1964. Both projects carried out important correction works in the Arás torrent and its tributaries, and the reforestation of the upper areas of the watershed and the hillsides draining directly to the torrents. The last project affected only to the drainage net and it was carried out between 1996-2000, after happen the event of the 07-08-1996.

Methodology

The methodology developed to assess the effectiveness of the W-F-R is structured around two issues: *I)* the physical description of the watershed and its temporal physical-biological evolution as a result of the W-F-R, and *II)* the research about criteria and parameters to use to assess such evolution. The first issue deals with: a) all the operations required describing the current physical state of the watershed, overall regarding the forest cover, and b) the specifications of the restoration works executed in the basin, its justifications and description of the current state. The second issue establishes experimentally corroborated logic criteria from which parameters are selected. These parameters are used to assess the capacity that the mountain watershed achieves in the control of natural risks as the effects of the W-F-R consolidate.

Three lines are established to assess the protection capacity of the basin before natural risks regarding if it comes from: 1) forest covers; 2) correction works; and 3) synergies that surge along the consolidation of reforestations and works executed in the basin. In the line 1) the criteria followed to define the grade of protection supplied to the basin by the forest cover consisted into analyze the approximation of those forest covers to the definition of protective forest before each natural risk from the results of the INTERREG III project (Gauquelin & Courbaud, 2006, Licini & Pasquettaz, 2006). Line 2) uses as a basis the improvement of the behaviour of the water and sediment cycles in the watershed during torrential precipitations as the W-F-R provides effects (Mintegui & Robredo, 2008; Rey *et al*., 2009). In order to assess the synergies of line 3 the grade of achievement of the objectives of the W-F-R in the basin was used.

Results

The basin of the Arás torrent is practically deforested when the first W-F-R starts (1907). The upper left image in the Figure 1 shows correction works in the gorge of the Arás torrent during the second W-F-R project (1963) and the upper right image shows the same place after the event in 07-08-1996 when the flow eroded the channel deeply but the forest cover stayed. In the lower images, on the left appears the map of the watershed of Arás torrent (2011) with the four types of protector covers before several natural risks established with the methodology. On the right shows a panoramic view of the basin in 2001.

The rain gauge of Aso (1970-2006) inside the Arás watershed and Biescas (1927-2012) close to the watershed, were chosen in order to analyse the behaviour of the water and sediment cycles in the basin of the Arás torrent, because they had the longest temporal record. Afterwards, torrential events of every maximum monthly precipitation provided by those rain gauge in the period recorded were simulated. This analysis confirmed that in theory torrential rises of the Arás torrent larger than those in 11-06-1929 and 07-08-1996 could have occurred. In those dates there were disasters, but the torrent didn't caused problems since the 60's decade of the XX century and the perception of security was absolute.

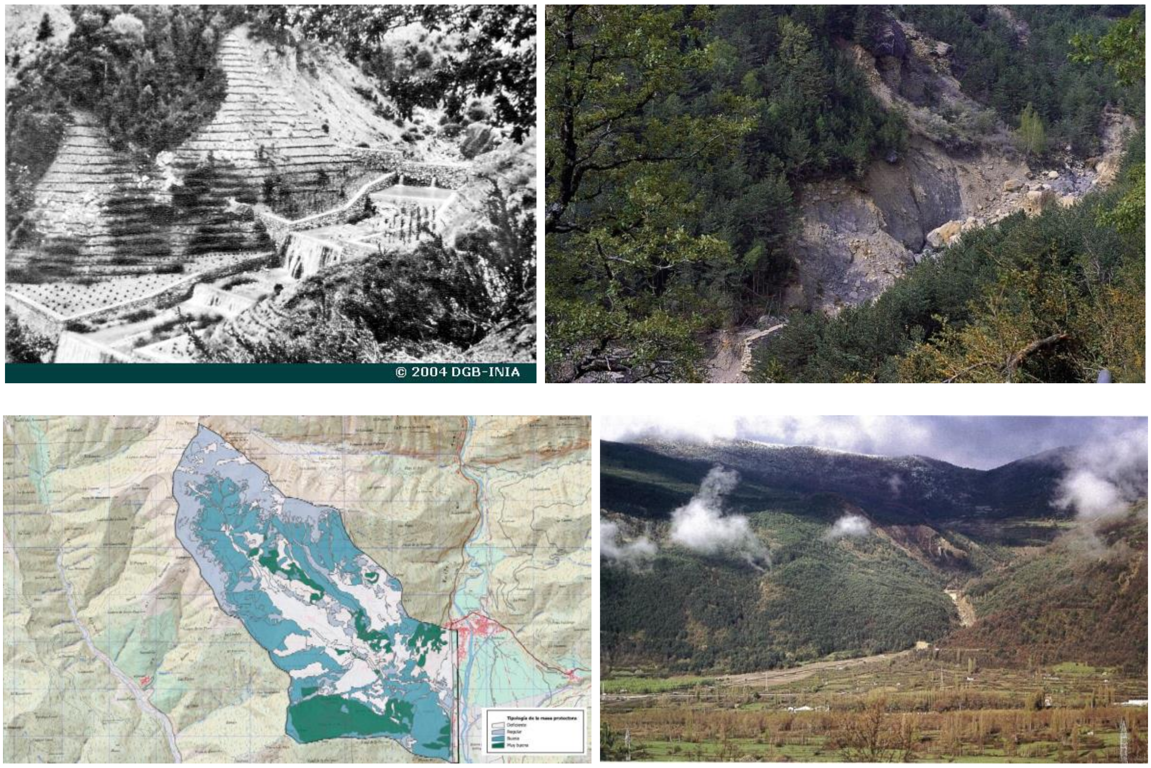

Figure 1 Basin of the Arás torrent. Top: gorge of the torrent in 1963 (left), in 2001 (right). Bottom: map of the basin with the four types of protective forest cover defined in the methodology (left), panorama of the torrent in 2001 (right).

Discussions and Conclusions

The forest cover created with the reforestations of the basin of Arás torrent has contributed to soften the torrential geo-dynamism effects and to reduce avalanches and landslides in the headwaters. Although the Arás torrent was the scene of a tragic event in the evening of 07-08-1996, when a strong flood devastated Las Nieves campsite placed on the alluvial fan. What happened doesn't invalidate the convenience of carrying out W-F-R projects in the torrential mountain basins, but shows the need of managing the territory before the natural risks.

Acknowledgments

Authors wants to express their gratitude for the authorization for the photographs in Figure 1 to TRAGSA Group, to José Nicolás Rodríguez and to INIA.

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Restoration of incised streams using large wood – long-term effects on a silt- and sand-bed stream in central Germany

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Abstract

In 1998, six trees were logged into an incised channel to create two log jams. In 2014 we surveyed cross-profiles, wood storage and leaf-litter retention. In the restored section, the variation of parameters like channel width, streambed width, water depth, and channel depth was significantly higher than in the reference section. The amount of large wood decreased by 24% and the spatial orientation of the cabled logs had changed into hydraulically less effective structures. To reverse channel incision further, the orientation of the logs should be improved and gravel should be added upstream.

Keywords: C*hannel incision; Channel morphology, Log jam; Leaf-litter;*

Introduction

In North America, the use of large wood for stream and habitat restoration has a long tradition, especially in forested catchments. However, this approach first became popular in the 90s to restore regulated streams in the densely populated, cultural landscapes of Central Europe (Reich et al., 2003) as wood has actively been removed from most streams for hundreds of years (Gurnell et al., 1995). The research project „Ecological, technical and economic aspects of stream restoration with large wood“, began in 1997, funded by the German Environment Foundation to test this method on a stream heavily degraded by channel incision. Large wood was installed in the stream in January 1998 (Fig. 1), but only little effects on channel morphology could be observed until 2001 when funding of the project ended (Reich et al., 2001). Today, short-term data on the success or failure of many restoration projects is available, but long-term observations are still scarce (Kail et al., 2007). Therefore, the objective of this paper is to monitor and to assess the long-term effects of using large wood for stream restoration 17 years after the wood was installed.

Figure 1: The Eifa (January 1998), with a considerable incision of the channel (left), and one of the two installed log jams (right).

Study Area

The Eifa is a fourth-order stream with a mean annual discharge of approximately 243 l/s and a mean low flow of 68 l/s (10-year flood: 3,2m³/s, 100-year flood: 8,8 m³/s) (Reich et al., 2001). It is situated in a lower mountainous region near Alsfeld, Hesse (Central Germany). The sinuous stream channel demonstrates severe incision of about 3 to 4m. Stream-bed and banks are characterized by sand and silt.

In January 1998, two log jams were created by logging six trees (*Picea abies*, *Pinus strobus,* and *Populus sp*.) at the margins of the channel and adjusting them in the channel using a winch. These logs were between 12 and 26 m long, with mean diameters between 17 and 60 cm. They were not expected to float downstream during floods, but permission for this experiment was obtained only on the condition that they were cabled by steel ropes. However, the cables were designed generously, so that the logs could move at least for a few meters.

Materials and Methods

In November 2014 we monitored several parameters during low flow. We surveyed cross profiles along the 130 m long restored section, a 50 m long upstream and a 200 m long downstream section. Length and diameter of all pieces of large wood (diameter >10 cm) within the bank-full channel were measured and their orientation in the channel was recorded.

To estimate the retention of leaf litter, we carried out a drift experiment, using leafs of *Ginkgo biloba.* In each experiment 3000 leaves were released into the channel during low flow and collected 50m downstream with driftnets and counted over 20 minutes in intervals of two minutes. The first experiment covered 50m of the downstream section, the second experiment included logjam II, and the third experiment logjam I further upstream, both in the restoration section. All three experiments were carried out within two hours.

Results

In 1997, before the restoration experiment started, we found approximately 3m³/100m of large wood in the restoration section. By adding the six trees, this amount increased up to 11,7m³/100m in 1998. In 2014 we found 8,9m³/100m in the restored section. In1998 most of the wood was clustered in the two log jams, but in 2014 the wood was distributed over the whole section more equally. Four of the six cabled trees (spruce and pine) were still present, but had lost all their branches, were significantly shorter and did not form complex log jams any more. The two cabled poplar trees were absent.

In the first two years after the wood introduction, *Ginkgo* leaves were retained completely in the first log jam. Only nine (1998) and one (1999) leaves passed this 50m section within the first 20 minutes. The retention potential decreased strongly as 220 leaves passed this section in 2014, which is still considerably higher than prior to the wood introduction (approx. 785 leaves/20 minutes).

In the restored section, the variation of parameters like channel width, stream-bed width, water depth, and channel depth was significantly higher than in the reference section. The analysis of the cross-profiles indicates only little aggradation of sediments in the channel and a tendency to develop a secondary floodplain only in some parts of this section.

Discussions and Conclusions

Obviously, there was no strong input of wood from the riparian zone or from upstream during the last 17 years, as the amount of large wood decreased by 24%. Four out of six cabled logs were still present but lost needles, branches and parts of the main stem. They also changed their spatial orientation into hydraulically less effective structures. This could explain the observed decline in the retention of leave litter. To reverse channel incision further, it would be necessary to improve the orientation of the logs to be hydraulically more effective again. Bed-load is dominated by sand and silt, while coarse sediments are missing probably due to human impacts upstream. Therefore, the creation of gravel deposits upstream could improve aggradation and support lateral erosion. The restoration in 1998 was significantly cheaper (29 €/m) than a conventional restoration project in this section would have been (170 €/m) (Reich et al., 2001), but the results indicate that more funding is necessary to further improve the restoration project.

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Perception of in-stream wood related to floods in Mountain Rivers in the Iberian Peninsula

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Abstract

In-stream wood is an essential component on stream ecology, river dynamics and channel restoration. In Spain public perception of wood in rivers is generally very negative. Wood is seen as a source of danger, and the common management strategy is to remove it from the channels, together with the elimination of sediments and living vegetation. Survey was conducted online, and in person, and we surveyed for the first time controlled groups of individuals living in areas affected and non-affected by flash floods in south-central Pyrenees, in the Ebro River and in the Spanish Central System. The perception of wood was assessed using a well-known questionnaire based on visual perception of stream and river scenes (20 colour photographs), according to aesthetics, naturalness, danger and need for improvement. In addition we requested information about personal opinion regarding river management. Preliminary results confirmed that channels with wood are considered more dangerous, and they are associated to flood risk.

Keywords: *In-stream wood, flood, public perception; river management, channel cleaning*

Introduction

Extensive literature now exists describing the positive influence of large wood (LW) on stream ecology (Gregory et al., 2003), and on river dynamics in general (Gurnell, 2012; Wohl, 2013, Le Lay et al., 2013). In addition, wood reintroduction is a method increasingly used in restoration projects to improve the hydrological, morphological, and ecological status of degraded streams and rivers (Kail et al., 2007).

However, in many regions LW is still perceived as a hazard to be avoided in order to prevent flooding and damages to infrastructures (Piégay et al., 2005). Despite the efforts from scientists to promote and emphasize the positive ecological role of wood, to highlight the negative consequences of wood removal; nowadays in much national legislation, landowners or public agencies are required to remove wood from rivers. This is the case of Spain, where a common management strategy is to remove LW from the channels. This is usually defined as "cleaning" or clearing of rivers and includes as well the elimination of sediments and living vegetation together with dead wood, and which is now the subject of ongoing debate (Correa, 2013; Ollero, 2013).

The European Water Framework (2000/60/EC) and Flood Directive (2007/60/EC) provided a legal framework favouring the good ecological and geomorphological conditions of water courses, and this may lead to conflicts concerning the current management of large wood in Spain. Consequently, if we discard the assumption that LW is the problem, the approach could, for instance, be redefined as the inability of infrastructures to allow large wood to pass (Lassettre and Kondolf, 2012). It has been shown that most of the time wood lies relatively stable in the channel and becomes potentially hazardous to human infrastructure only during short and infrequent high-magnitude events (Mao et al., 2013). Therefore, the challenge is to maintain the equilibrium of the good ecological and hydromorphological condition of rivers and, at the same time, analyse and manage the potential risks (Mao et al., 2013).

However, public perception of wood in rivers, especially in those areas affected by floods where wood could play an important role may be decisive when in-stream wood management strategies are defined. We followed up here a well-known perception study, the one presented by Piégay et al., in 2005, in order to test this hypothesis. This study based on a survey using pictures from different river morphologies with and without wood was already applied under several circumstances (different population groups, different countries, etc.). Here we surveyed for the first time controlled groups of individuals living in different mountain areas recently affected by floods. In addition we conducted an online survey to extend our interviewed population non-affected by floods.

Study Areas

Surveys were conducted in areas affected by recent flash floods in the Pyrenees: i) Canfranc Valley, at Villanúa and Castiello, the most affected sites by the October 2012 flash flood, ii) Benasque Valley, affected by the June 2013 flash flood, at Benasque and Castejón towns, iii) Arán Valley, also affected by the June 2013 flash flood, at Vielha town. We also surveyed population living in the middle Ebro River basin (surveys carried out in Pradilla de Ebro), where damages in agriculture are common as a result of frequent floods, the most recent in March 2013. In the Spanish Central System surveys were carried out in the village of Navaluenga, which is frequently affected by floods causing damages to infrastructures and buildings nearby the river (although the most recent was in 2001). In general in the Iberian Peninsula the intensive territorial occupation during the last 50 years has lead an increase in flood exposure, thus flood risk is increasing as a result of the poorly controlled urban growth.

The online survey was designed using the open source platform *LimeSurvey* (www.limesurvey.org) and it was focused on population non-affected by floods and located all around the Iberian Peninsula, including groups of university students, researchers and professors, technicians and managers specialists in flood risk analysis.

Materials and Methods

The perception of wood was assessed using a questionnaire (online and in person) that was based on visual perception of stream and river scenes. Participants were requested to rate 20 colour photographs that portrayed reach views of streams (channel width from 2 to 5 m) and rivers (channel width wider than 10 m) using a numerical scale. The pictures comprised 10 river scenes (five with wood and five other scenes without) and 10 scenes of streams (again five with wood and five without). They reflected a variation of temperate stream and river types from mountain, piedmont, and lowland regions. Pictures, information on the selection procedure of the photographs, and related information are published in Piégay et al. (2005).

Participants were told the aim of the survey was to evaluate various river scenes. They did not know that the survey focused on the perception of wood. Respondents were asked to rank each scene from 0 (lowest degree of agreement) to 10 (highest degree of agreement) according to aesthetics, naturalness, danger and need for improvement. In addition to the perception of the stream or river scenes, we requested information about personal opinion regarding river management and academic skills of the participants.

Preliminary results

Preliminary results from the surveys conducted in Pyrenees (120) show a similar perception in the different areas about channels, with significant differences between rivers and streams with and without wood.

Channels with wood are considered less aesthetic, although more natural. They are also seen as more dangerous, and therefore, they are associated with a need of improvement. However, there are exceptions and scenes without wood are evaluated with low scores aesthetically. Conversely, some channels with wood were also graded with high scores in relation to their aesthetics.

Results of the correlation analysis show significant positive correlations between aesthetics and naturalness, and between danger and need for improvement. Furthermore, there are significant negative relations between aesthetics and need for improvement, and between naturalness and need for improvement.

Finally, we observe an association between flood risk in the case of channels with wood, generally considered more dangerous. Respondents claim a high need for improvement, basically focused on cleaning of rivers.

The online survey was started by 441 people but it was only completed by 137, leaving 304 incomplete responses.

Surveys conducted in the Spanish Central System (47) and online will allow getting additional results, testing similarities and differences between regions and between population groups. In addition results from similar surveys in other sites will be also compared.

Acknowledgments: Authors thank all the interviews participants, and collaborators who distributed the online survey among colleagues and students. This work has been partially supported by the projects MAS Dendro-Avenidas (CGL2010-19274) and MARCoNI (CGL2013-42728-R) and the Dendrolab.ch (University of Bern).

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The effect of flexible vegetation on flow in drainage channels: field surveys under different growth conditions

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Abstract

A methodology for field data harvesting in vegetated channels is presented. By means of water pumps, different discharges are pumped into a naturally vegetated drainage channel located in Northern Tuscany. Velocity distribution and water level are measured by means of high-precision instruments for different discharges and different vegetation covers. Then, an estimation of roughness coefficients related to vegetation parameters such as height and density is proposed. Finally, a comparison with recently-developed formulas is presented.

Keywords:

In-channel vegetation, flow resistance, flood risk.

Introduction

The management of vegetation in drainage channels represents one of the main issues for land reclamation authorities during spring and summer seasons. In fact, the presence of high concentrations of nutrients combined with a constant water level enhances the growth of aquatic and hygrophile vegetation within the riverbed and banks. This vegetation is constantly removed in order to maintain a sufficient discharge capacity of the channels in case of flood events. At the same time, it should be considered that drainage channels constitutes a fundamental habitat within the agricultural environment. Therefore, estimation of vegetation effects on flow conveyance is useful for channel management planning.

In the literature, recent works (e.g. Nepf, 2012; Aberle and Järvelä, 2013) have proposed various formulas for estimating flow resistance in the case of different vegetation types (such as aquatic or riparian); however, these formulas were typically derived from laboratory analyses using in some cases, artificial vegetation. Therefore, their application to the field is uncertain. The objective of this work is to assess the effect of grass and reed vegetation, typically growing in drainage channels, on flow rating curves (i.e. in terms of reduction in discharge capacity, water level rise) and on velocity distribution in given monitoring cross-sections.

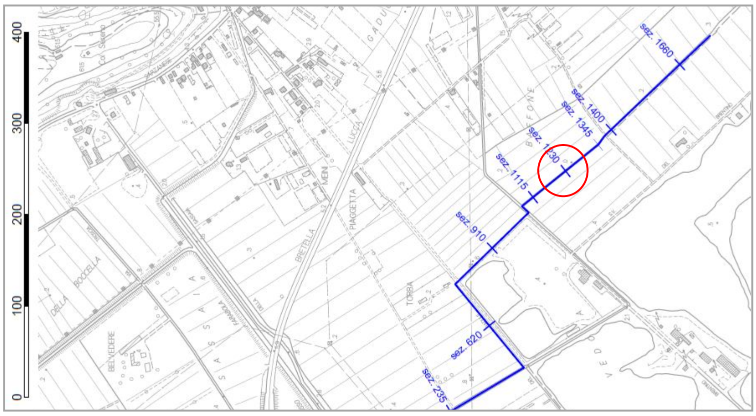


Figure 1: Location of the experimental stretch and of the monitoring station (sect. n°1230), where hydrometric measurements will be carried out.

Study Area

The location will be a straight stretch of 400 m long channel in the Versilia-Massaciuccoli reclamation area.

A dense network of channels drains the fields, which are located below the sea level. A densely urbanized area is located nearby, so that the management of in-channel growing vegetation is aimed to minimize the risk of flood.

Materials and Methods

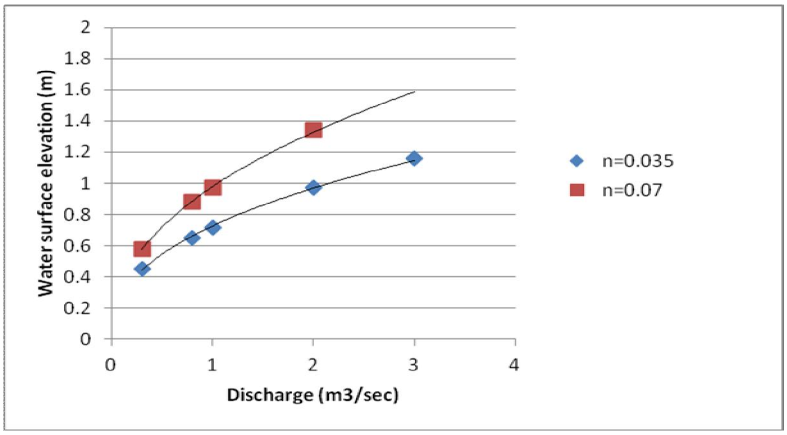
A field experiment is scheduled for spring 2015 aimed at measuring various parameters of the water flow for different discharges and under different vegetation conditions. Field works will be supported by the Northern Tuscany land reclamation office's staff. Measures will be conducted in late spring (maximum vegetation growth), after a partial cut, and after total removal. Discharge will be varied by means of a mobile water pump with a maximum discharge capacity of 0.8 m^3/s. The maximum discharge capacity of the reference section, using a standard roughness, is estimated to be around 2.5-3 m^3/s.

Figure 2: View of the channel from upstream. Top width is 5.12 m, base width is about 2.5 m; the average slope is 0.0002. Flow parameters will be measured in different vegetation scenarios.

The water surface profile will be traced for every discharge using a total station. On a central monitoring section the flow velocity distribution will be measured by means of a current meter. The flow rating curve will be obtained for the monitoring section under different vegetation layouts. Also the characteristic of vegetation will be measured, in order to compare the results with the ones of other authors (e.g. Kouwen,1973, Nepf, 2012). An intermediate condition between maximum growth and total removal of vegetation will be measured, in order to test the sustainability in the Versilia area of the "gentle management" proposed by Madsen, 1995. The slope area method will also be applied to determine the discharge, and results will be compared with the ones obtained by means of the velocity measurements. This last step will be a help for future works in the same field of study, when a similar approach will be applied on a river stretch with denser rigid cover.

Expected Results

We expect to obtain the rating curve for each vegetation scenario. Flow resistance coefficients will be obtained from the field measurements and compared with estimates from the literature; this will allow calibrating current formulas. An HEC RAS simulation was performed in order to figure out the water level corresponding to the maximum discharge obtainable by means of the water pumps, to control the eventual flood risk during operations. Moreover, a prediction of velocities was obtained: with a discharge of 0.8 m^3/s the average velocity is computed to be 0.28 m/s. A simulation of two different Manning coefficients is here presented. For given discharges, differences in water levels are appreciable.



Graph 1: Flow rating curves for different Manning coefficients in section 1230.

Future Developments

A future development will include similar measurements on a natural river in central Tuscany, covered by shrubs and rigid vegetation. Different areas will be surveyed, monitoring the changes in the vegetation cover before and after management cuttings together with the water levels for known discharges. Also in this case, results will be compared with the two existing models already mentioned before and with literature (Nepf, 2012, Kouwen, 1973, Baptist, 2007, Thompson & Robertson, 1976; Guarnieri and Preti,2007; Errico and Preti, 2011, 2012; Jalonen *et al*., 2013). An estimation of the corresponding roughness coefficient will be carried out. Future studies will include also a comparison between field data and different remote sensing methods for roughness parameters survey (Forzieri et al., 2012).

Acknowledgments

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Management plan for riparian vegetation in the Orba Torrent, Alessandria, Piemonte Region, Italy

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Abstract

This article describes the Riparian Vegetation Management Plan of the Orba torrent. The methodology, provided by The Basin Authority of Po river, defines actions related to the objectives of reducing flood risk, improving natural habitat conservation and landscape quality.

Keywords: riparian forest, plan, river, flood risk, habitat conservation

Introduction

Management plans of the riparial vegetation were carried out in the framework of the ALCOTRA "EAU CONCERT" project, whose aim was the preservation and the quality improvement of the fluvial ecosystems in the transboundary area between Piemonte and Rhône-Alpes Regions. Then Piemonte Region started a new phase of integrated planning of fluvial areas involving not only Dora Baltea river, object of the Eau Concert project, but also Stura di Lanzo and Orba.

The planning methodology came out from the collaboration between Tutela Qualitativa e Quantitativa delle Acque Regional Sector and the Istituto per le Piante da Legno e l'Ambiente (IPLA) supported by the Autorità di Bacino del Fiume Po (AdBPo) and the Agenzia Interregionale per il Fiume Po (AIPO).

Study Area

The study area includes the Orba torrent in Alessandria Province from the boundary between Piemonte and Liguria region (the upper part of the Orba catchment is in Liguria) to the confluence with the Bormida river. Orba is a typical appenninic stream at pluvial regime. In the first tract from the flow into the alluvial plain up to confluence with the Piota torrent Orba is characterized by a confined bed whose dynamics is limited by mountain slopes and terraces. From the Piota confluence onward Orba torrent riverbed is sinuous with a good presence of gravel bars and vegetated islands even if the morphology is influenced by the presence of hydraulic transversal works (weirs and crossbars). Straight tracts are locally developed immediately uphill of the crossbars while downhill sometimes anastomosed channels can be observed.

The riverbed profile presents a steep bank, often consisting of embankment made by prisms of concrete, with a tree-shrub linear hedge, and a gentle slope on the opposite bank in continuity with the floodplain mainly characterized by the presence of bars or islands permanently vegetated, with shrubby willow, willow and poplar groves (black and white poplar and white willow more sporadic) and black locust stands mixed with elms and oaks (hybrid oak oak).

The riparian vegetation has generally semi-natural features, also in consideration of the low incidence of invasive alien species. Overall it's young-adult stands, rarely aged, also for generalized regeneration operated by the floods, with good structural stability in the medium term (5-10 years).

The stream regime and the water supply for irrigation purpose that limits the flow during the summer, are providing the conditions for a rapid colonization of bars and isles by the vegetation on the riverbed.

Materials and Methods

The management plan is developed through the following stages: 1. definition of the state of art for the different morphological, hydraulic and vegetation components; 2. definition of the homogeneous segments, with reference to pre-defined environmental, morphological and hydraulic parameters; 3. setting general and specific objectives; 4. Definition of the interventions, looking for a better match between the current and wished status, in coherence with the objectives.

The general objectives, properly declined in specific depending on the context, are related to the flooding and erosion risk, land use and human activities, landscape improvement, definition of proper rules and spaces for sustainable farming and forestry, citizen's fruition and natural heritage conservation.
The methodological approach also includes a property survey as a key element to better achieve the objectives and to fulfil the planned interventions.

Results

Orba has been divided into 11 homogeneous sections, 10 for the alluvial plan and one for the mountain area, with a total analysed surface of 5,600 ha. In the alluvial plain the most important forest categories are the willow and poplar that are widespread with different degrees of mixing between black poplar (dominant) white poplar and white willow, together with black locust, sometimes prevalent.

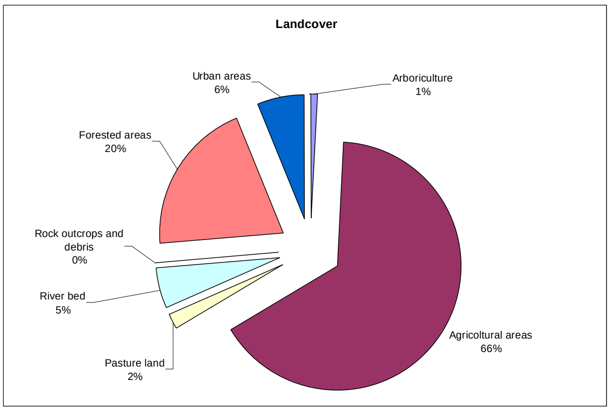

Figura 1: Percentages of different land cover categories

The plan objectives must take into account the various environmental issues (hydraulic, morphological, ecological requirements) as well as the economic factors and the opportunities related to the overall valorization of the river areas also from the point of view of the recreational uses.

In riparian forest the main objectives are: reduction of the flood risk, erosion and log floating in the most vulnerable river sectors, increasing the effectiveness of the water lamination areas, preservation and improvement of semi – natural habitats, and increasing of sustainable recreational uses.

The intervention for forests envisage different management approaches, depending on the objectives, location (river bed with both shores, floodplain and flood plain) and the presence of critical situation (infrastructure, water works, embankments in erosion, etc.). In order to reduce the flood risk and to keep the riparian forest young, flexible, reducing the risk of falling in the river bed of large trees is considered a selective cut, coppicing or clear felling on small areas. In water lamination area, where the risk of erosion is low, are considered selection felling, thinning / conversions towards the high forest, mixed and uneven aged, for the improvement of the composition and structure of the forest.

General considerations were also taken into account in the definition of the planning strategy and its main objectives. It's worth remarking that flood are usually events occurring in a short amount of time since the current proceeds downstream with remarkable speed; therefore the vegetation can play a unique role in reducing flow speed in areas, that are prevalent, where flood risk has a low rates due to the low presence of settlements and infrastructures. The critical issues related to the presence of vegetation are modest and localized: slope erosion, bridges, embankment threatened by tree failure and two islands in which the Management Plan of Sediments (PGS) identified the sediments removal as a priority.

Figura 2: Vegetated island near Predosa (AL). During the last flood events (october 2014), weren't observed remarkable erosion and log floating phenomena and this aspect demonstrates the good hydraulic functionality of the present vegetation cover along the stream.

Discussions and Conclusions

The management of the fluvial streams is then a complex theme of prevalent public interest therefore needing the attention of the local technicians and administrators driven by the high sensitivity of the public opinion on these subjects. An hard task is conciliating many different and sometimes conflicting interests such as hydraulic safety, natural habitat conservation, ecological network connection and the economic expectations of the various involved sectors: agriculture, poplars cultivation, mining and recreational activites. In order to provide effective results the plan must be based on integrated management tools covering all the interest themes. In absence of adequate planning the riparian vegetation management can suffer the high pressure of the local communities both for lack of information and for economic interests (e.g. gravel extraction, wood for energy supply chains). Actually on the Orba torrent a lot of clear cutting on willow and poplar high forest were recently done on riverbed, banks and flood plain making an improper use of the hydraulic management priority allowed by the regional law. These interventions show a severe impact on the riparian environment without any apparent advantage in terms of hydraulic risk reduction.

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Management of riparian forest in the Reno River basin, Emilia-Romagna

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Abstract

The management of riparian forest is often complex due to environmental, hydraulic and recreational demands. Silvicolture can provide sustainable and multifunctional solutions ensuring a fair balance between the different opportunities. Knowing and understanding the roles that vegetation plays or can play could be very useful not only for the proper management of resources but also for providing information for a balanced land planning which in our case is for combining the objectives of preventing flooding events and ecological enhancement. The riparian vegetation is affected, in time and space, by changes due to natural and human factors, both in eco-structural characteristics and range. The formulation of guidelines for a sustainable management and, where possible, for increasing biodiversity and river restoration can be complex and requires a multidisciplinary approach especially in high flood hazard areas. The use of G.I.S. allows territorial themes to be processed quickly and easily. Field surveys and analysis of studies, projects, etc. allow a framework on characteristics of the forests and the role they play in relation to specific needs to be obtained. By land analysis it is possible to identify "homogeneous areas" according to groups with similar characteristics in relation to physical, environmental and, human factors. For each homogeneous area models of management related to sustainable silvicoltural treatments in the context of a proper cost-benefit ratio are proposed. The methodology provides a valuable support for the formulation of guidelines and of multiannual plans for a balanced use of forest resources within the river banks.

Keywords: hydraulic hazard, riparian buffers, sustainable management, silvicolture

Introduction

This study is linked to previous research developed and tested in collaboration with the Department of Tree Cultivation (forestry section) of the University of Bologna and is designed to combine the objectives of flood prevention (minimizing hydraulic risk) with the conservation and improvement of waterways biodiversity. This aim arises from the “Water Framework Directive 2000/60EU” and “Floods Directive 2007/60EU” and falls within the objectives of the Department of Environment of the Emilia-Romagna Region. Riparian forest is a habitat which depends mainly on fluvial dynamics. Until recently, the hydraulic safety of waterways in populated areas was subject to intense works of "remediation" largely entrusted to the dyke systems and other hydraulic engineering solutions without taking due account of the role that the vegetation could have. Until a few years ago riparian woods were subjected to frequent and intense coppicing or were transformed in cultivated fields (arable, orchard, etc.). Today the vegetation can be considered as a useful tool in the defence and preservation of soil richness and in the regulation of flood events in all those situations where the banks are not strictly necessary.

Study area

The methodology was applied on the riparian vegetation of the main river banks of the Reno basin on an area of about 139 km^2, which represents 18% of the whole Emilia-Romagna region and 6% of the Padania Plain. The Reno catchment has a mountain area of about 2,600 km^2 that extends over the Tuscan-Emilian Apennine range. The prevailing lithological types are sedimentary formations, such as clays and limestone. These formations have an intrinsic tendency to disruption and erosion, which is usually magnified by climatic or even human factors. The climatic features show both heavy rainfall inputs during autumn and winter and droughts during summer with a mean annual precipitation which varies from 800 to 1400~1800 mm, depending on the altitude. Until the middle of XX century the population were mainly dedicated to agro-forestry activities and therefore strongly dependent on natural resources. Nowadays the human density in mountain regions has lowered to less than 70%, with a high concentration in urban areas along the valley floors; landscapes offer green covers, mainly formed by rangelands, young woods and farming fields, and streams are completely covered by riparian forests of willows, alders and poplars. On the flat areas of the Reno River system, one sees the result of heavy land reclaiming activities, started during Roman times and developed especially between the XVIII and XX centuries. The territory that was occupied by swamps and marshes has been almost completely drained by artificial filling. The rivers that use to spread their waters and sediments over the lower plains between Bologna and Ferrara are now forced into a system of fluvial embankments that have been continuously increased in height. Expansion of urban areas has sometimes reached the fluvial embankments without leaving space for a future enlargement of the river section. The total length of embankments in the Reno river system nowadays is of 840 Km (240 Reno, 600 tributaries). The Reno river and its tributaries are anyway important ecological corridors with a good biodiversity and cross strongly modified landscapes with rare natural areas. Riparian forests are characterized by the presence of willows, poplars (mainly *Salix Alba, Populus nigra, Populus alba*) with the rare *Alnus glutinosa* and often with exotic alien species as *Robinia pseudoacacia, Acer negundo, Amorpha fructicosa* and *Ailanthus altissima.*



Reno river basin: location, plain and hill riparian buffers

Materials and methods

The survey is developed in two steps by simple methodological criteria. The use of G.I.S. allows the analysis and processing of data and of geographical themes.

Step 1: Identification of silvicoltural models for a sustainable and multifunctional management

Field surveys, analysis of previous research, and other information obtained by stakeholders allow us to obtain an up-to-date framework of interest factors and their role in decision analysis. In particular details are provided on:

1. Typological classification of the rivers in relation to territory (mountain, hill, plain, etc);
2. Classification of hydraulic hazard (three levels) for the surrounding areas (landslides, flooding, etc);
3. Degree of environmental protection (regional parks, nature networks, no protection, etc.).

By overlapping and comparing these three themes it has been possible to obtain "homogeneous areas", joining groups with similar characteristics in terms of both physical, environmental and anthropic factors: every single group corresponds to different combinations of factors. For example:

Group 1: includes all features of rivers with hydraulic hazard high, environmental protection, plain areas, etc.
Group 4: includes all features of rivers with hydraulic hazard low, no protection, mountain areas etc .

To each group a model of management applying specific silvicoltural treatments has been assigned.

Step 2: Identification of parameters and characteristics of forests

On different sample areas covering the 25% of the entire catchment surface, specific forestry measurements (diameter height of plants, basal area, density, age, undergrowth coverage and type, etc.) were made. These surveys have enabled the calculation of biomass volumes identifying three different groups of forests stands. Every group is representative of the various situations depending on age, origin (seed, coppice) density, structure, soil, etc. The extension of these results to the entire buffers streams (several kilometres for every river) has been made possible by photo-interpretation analysis and field surveys. The comparison between biomass values and silvicoltural models allows us to obtain cost / benefit estimates as a result of the management proposed.

Results

1.Identification of homogeneous groups and application of silvicoltural models

The study has identified 14 different homogenous groups: the most common refers to mountain sections with low hydraulic hazard far from urban areas. The most difficult to manage is the group characterized by aged forest located in strong hydraulic hazard zones (channels with dykes) and in protected areas where a fair balance between cutting and conservation of mature trees must be found. In all cases distinguishing the riverbed from the banks, the silvicoltural treatments avoid cutting and provide:

-periodical cutting of mature trees within the active river bed (to ensure a good flow of water)
-silvicoltural management on the banks and terraces / floodplains, providing:

- natural evolution (no intervention, maintaining the current status, with a periodical monitoring)
- lightweight intervention (thinning up to 30% of mass present)
- intensive intervention (thinning up to 70% of mass present)

Cutting is applied only where strictly necessary and has the purpose of maintaining the vegetation in youth conditions, with maximum flexibility and resistance. In situations (very common in the Apennines) with low hydraulic risk, interventions are not expected. In case of intensive cuttings in environmentally valuable areas (such as protected gallery forest) thinning is subject to impact mitigation measures articulating and limiting forestry activities in time and space. Compensatory measures related to the disturbance of cutting may provide reforestation, forest bioengineering or river restoration. The percentage distribution of silvicoltural models is reported in fig.1

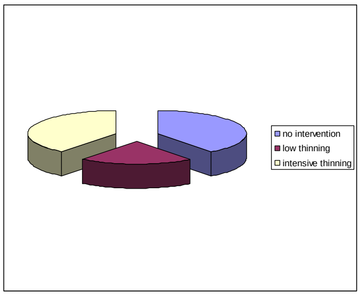

fig 1

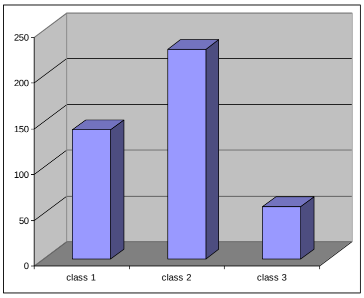

fig.2

2. Determination of standing volume

The surveys have identified three groups which are representative of different situations:

- class 1: sapling/pole forest in evolution (from 0 to 10 years) with biomass volume 0 to 100mc per hectare
- class 2: young forest (10 to 20 years) with biomass volume from 100 to 200mc per hectare
-.class 3: mature forest (> 20 years) with biomass volume > 200mc per hectare

By assigning each group an easily identifiable pattern on satellite images (directly related with age, density and crown tree diameter) it has been possible to extend this classification to the whole buffer streams in each of the three groups, obtaining the distribution as seen in fig.2 (hectar distribution in a sample area). Here the average growing stock of biomass is approximately 140m3 / ha.
By overlaying and comparing the amount of standing wood volume with silvicoltural models (% of thinning) it is possible to obtain a cost / benefits evaluation in economic and ecological terms of the planned management.

Discussions and Conclusions

The methodology, which is simple and suitable for application also on a large scale, provides valuable support for the formulation of guidelines for long-term plans concerning a sustainable use of forest resources as in the case of public lands along river banks. Silvicolture can provide multifunctional solutions for solving problems and finding balanced solutions for combining hydraulic risk, biodiversity conservation and recreational enjoyment. This aim can be very difficult when the presence of mature and protected gallery riparian forest is not compatible with the hydraulics characteristic of artificial channels in high flood risk territories. Some thinning has already been conducted over the past three years and specific monitoring to verify the processes of forest regeneration (species, density, growth, etc.) in relation to the type of intervention is ongoing.

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Large wood in headwater intermittent channels key for basin scale dryland riparian system health

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Keywords: large woody debris; intermittent systems; floodplain reconnection; watershed restoration

Extended Abstract. Global arid and semi-arid (dryland) monsoonal rainfall systems are driven by extremes, and characterized by widespread flooding and extended droughts. Because flood water often runs off too quickly to benefit agriculture, many communities experience critical water scarcity. Much of the world's riparian areas have been degraded. New Mexico and Arizona alone have lost more than 90% of their riparian areas since pre-settlement times (eg. Krzysik, 1990), ecosystem services have declined, and the riparian loss has resulted in increased flood energy and more frequent catastrophic events. In dryland regions, most perennial flow has become intermittent (Gleick, 2003). With increased aridity and water appropriation, this trend will increase (eg. Döll, 2012). While constraining rivers with levees and dams is believed to have increased vulnerability to natural disasters by degrading the buffering capacity of the natural system and increasing human exposure to risks (eg. Haeuber & Michener, 1998), evidence suggests that reconnecting floodplains on a watershed-scale will be key for restoring resilient ecosystems, driven by the benefits to control floods and increase goods and services (Opperman et al., 2009, Molles et al., 1998). Restoration of riparian buffers, including agricultural fields, increases infiltration and shallow aquifer and ground-water levels (Fernald et al., 2007). This slows the delivery of water to surface reservoirs, further inhibiting evaporation that provides no local ecosystem services that now can be available for vegetative transpiration, which is necessary for generating a host of mutually reinforcing ecosystem services (Ponce, 1995).

Restoration of natural ecosystem functions has been shown to be essential for enduring resilience (eg. Berkes & Ross, 2013, Palmer et al. 2005). Restoration requires an integrated watershed scale approach (e.g. Wohl, E. et al. 2005, Bernhardt & Palmer, 2011, Hulse & Gregory, 2004), and becomes more achievable with both beneficial social and ecological goals (sensu Hulse & Gregory, 2004). While the boundaries of riparian zone ecosystems are recognized to "extend outward to the limits of flooding and upward into the canopy of streamside vegetation" (Gregory et al., 1991), challenges persist in holistic watershed approaches. This is particularly true in addressing waterways with temporary flow (Datry et al., 2014, Acuña et al., 2014), here termed intermittent, referring to all flows with an average over 30 years of five or more annual on flow days (Dahm, unpublished data 2015). The loss of large wood within riparian ecosystems resulting in "leakage" of

Figure 1: a) intermittent channel at time of log jam installation, b) same view after two monsoonal seasons

sediments, nutrients, and organic matter (eg. Wohl & Beckman, 2011, Wohl, 2011) points to the importance of restoration methods that reintroduce large wood into intermittent watershed headwaters. Some restoration successes in intermittent systems have been achieved; however, agency-accepted practices and methods widely utilized in the American Southwest are designed to either restore perennial, non-flood flows or to interact with only lighter flood flows (eg. USDA, NRCS, 2014).

To plan for restoration to socio-ecological resilience, this team began with a watershed-scale analysis at sites in New Mexico to identify desired benefits, and designed collaborative pilot study interventions that mimicked the natural flow regime (eg. Rood et al., 2003, Gregory et al., 2003) using the "floodplain large-wood cycle" of wood jams to create "alluvial patches and protect them from erosion" (Collins et al., 2012). Results have shown that the reintroduction of wood, here termed log jam interventions, achieves similar effects to large wood in perennial systems as summarized by Wohl (2011). These benefits include slowed flow energy through increased roughness; increased sediment, nutrient and organic matter deposition; increased vegetation and habitat recruitment resulting in increased infiltration; and improved resilience of the channel geomorphology through added diversity. Key differences from perennial dynamics lie in the energy levels from flows that have increased in dryland areas such as the Southwest - much of the uplands have been damaged by many years of heavy livestock use and fire suppression, greatly reducing the ability of the upland soils and vegetation to retain water during the spring snow melt and summer monsoon storms. Flood disturbances in these lower stream order dryland systems with characteristic higher gradients do not change linearly with scale. As found by Wilcox et al. (2003), vegetation loss can see the rate of run-off and erosion accelerate over time and cross the threshold of recovery without intervention. Dryland systems naturally have more tightly coupled relationships between water and vegetation than humid areas. Rather than soil storage capacity, the presence of concentrated bands of vegetation and other surface storage sinks controls the rate of infiltration. Without these bands of vegetation, dryland areas exhibit characteristic patterns of spots of woody vegetation surrounded by patches of bare ground that is often an indicator of desertification (eg. Kefi et al., 2007). Thus functions of discontinuity are critical to the health of these systems, which has been recognized as an important phenomenon within the entire riparian system (eg. Burchsted et al., 2013). Our specific approach to "step-down" the peak flows and reduce flooding was to strategically place log jams in a number of intermittent side canyons that flow into the watershed's perennial main stem, mimicking spatial patterns found in beaver activity (Burchsted, & Daniels, 2014). The design is necessarily a "soft" engineering approach (eg. Gleick, 2003, Bisson et al., 2003), while ensuring stability of the log bundle, porosity combined with flexibility both in length and movement in the wire cable tied to a deadman (tree or buried anchor) allows the natural flow energy to jam the bundle into a final resting location, preventing unintended erosion.

Watercourses with intermittent flow are important parts of the watershed, as they link the wet and dry ecological zones, disperse organic matter, nutrients and seeds, provide wildlife corridors and seed and egg banks, and disperse, store and process organic matter, nutrients and seeds (eg. Acuña et al., 2014). To achieve desired socio-ecological goals on a watershed scale, more study is needed to assess the extent to which a watershed requires land management practices that allow floodplains to perform the natural function of storing and conveying floodwaters. The stakes could not be higher. The Southwest in general is expected to face among the most acute effects of climate change and thereby is garnering worldwide focus. As fewer winter storms and warmer temperatures deliver less snowpack, areas reliant upon snowmelt will look to monsoonal systems for solutions to adapt to these growing extremes.

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