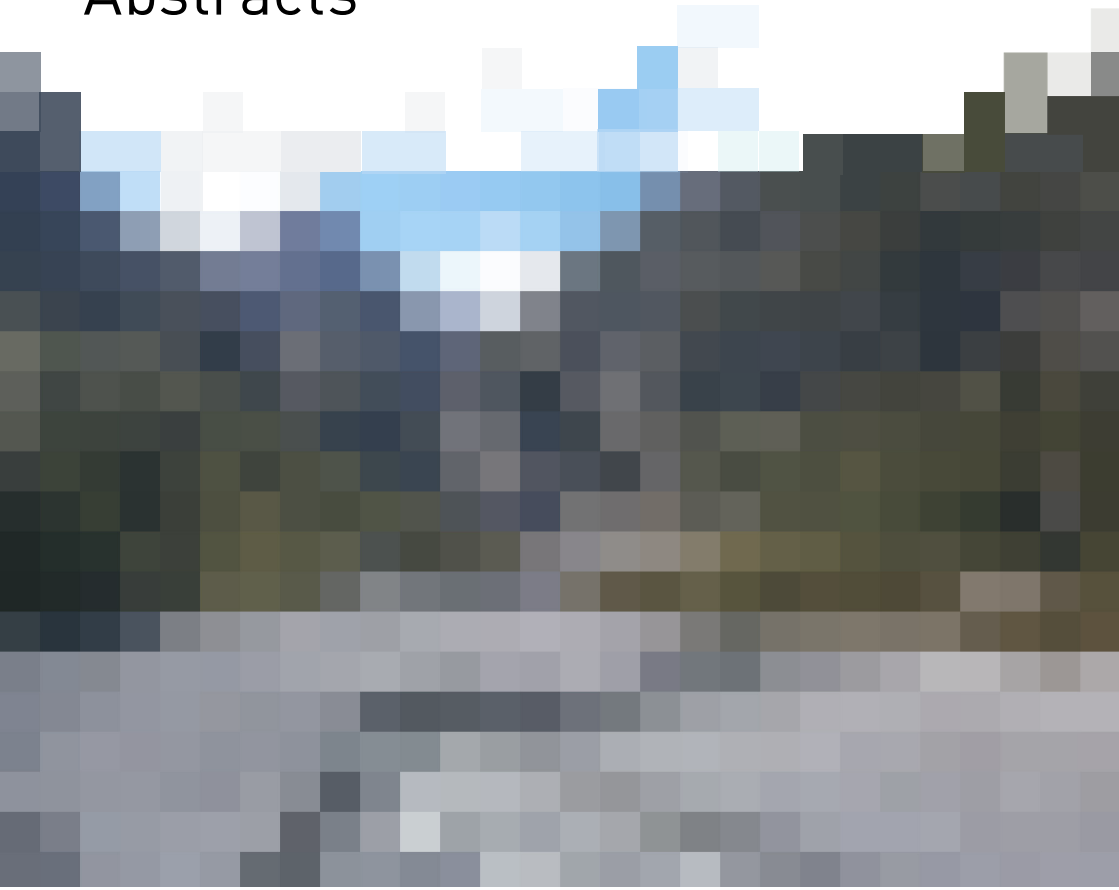
Sediment Management in Channel Networks: from Measurements to Best Practices

POSTER SESSION

Abstracts



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USING HIGH-RESOLUTION BEDLOAD TRANSPORT TRACER MEASUREMENTS TO INVESTIGATE THE CHARACTERISTICS OF BEDLOAD TRANSPORT OVER A LARGE URBAN FLOOD EVENT

Francesca Berteni, f.berteni001@unibs.it
University of Brescia (Italy)

Many regions around the world have experienced an increased frequency of large magnitude flood events arising from changing climate patterns. The role of solid transport in river dynamics is critical and not negligible in flood simulations. Indeed the severity of an event is often the result of the flood wave with elevated solid transport rates.
Mimico Creek (66.3 km2) is an urban gravel-bed channel in southern Ontario, Canada that has undergone intensive event-based sediment transport sampling (Helley-Smith) and inter-event bed material particle tracking (embedded RFID tracking) over a four year period between 2012 and 2016 (Plumb et al., 2017). On July 8th, 2013 a precipitation event occurred generating a flood in exceedance of the 100-year return period. Pre and post erosion surveys along a 2.1 km reach combined with the sediment transport studies and a proximal hydrometric monitoring station afforded a unique opportunity to evaluate the performance of various sediment transport models applicable to gravel-bed rivers for a short duration large magnitude low frequency event.
A HEC-RAS model was developed of the study reach and calibrated to a series of discharge events where in-situ bedload sampling occurred. Both step-wise discharge and unsteady flow simulations were evaluated to compare sediment transport rates for a range of transport models which included the

Meyer-Peter Muller (1948) and the Wilcock and Crowe (2003). In the case of the high magnitude flood event, the Wilcock and Crowe model compared closest to observed field conditions of bulk sediment transport rates.

The results of the calibrated model were used to calculate the mean travel distance of bed material using the expression for the volumetric rate of bed material transport (Hassan et al., 1992).

Modelling results, considering respectively step-wise discharge and unsteady flow simulations, found that mean travel distances varied widely (above and below mean observed transport distances) compared to calculated mean field distances. In some istances, the simulated mean travel distance is similar to the observed one. No relationships were found between mean tracer transport distance and peak discharge. The comparison of simulated transport distances against available field observations also provides another mechanism to validate appropriate transport equations; particularly where in-situ bedload sampling may not be available. (Berteni et al., 2018)

BALANCING HYDROPOWER DEVELOPMENT AND SEDIMENT STARVATION IN THE BALKAN: THE CASE STUDY OF THE VJOSA RIVER

Simone Bizzi, simone.bizzi@polimi.it
Politecnico di Milano (Italy)

The functioning of a fluvial ecosystem is controlled by abiotic and biotic factors and their interactions in space and time. Sediment transport and connectivity are key factors for the functioning of fluvial eco-systems. Disturbances to these factors, like the construction of dams for hydropower production, are hence bound to cause changes in the river ecosystems. These impacts should be carefully assessed when planning hydropower development in a basin.
Modelling cumulative dam impacts on sediment connectivity requires a whole-network perspective and it is rarely undertaken. CASCADE (CAtchment Sediment Connectivity And DElivery) is a network-scale sediment connectivity model that provides amount, frequency and provenance of sediment fluxes in any reach of a network. It is one of the first modelling framework that attempts to quantify sediment connectivity at the basin scale. It can assess cumulative effects of dam siting and sediment management measures on sediment routing at the basin scale.
In this work, we propose a new version of the CASCADE model, where: 1) sediment supply from each source is described not by a single sediment size, but as a distribution of sediment classes, and 2) calculation of transport capacity is based on the empirical Wilcock and Crowe equation.
This new framework is applied to the Vjosa basin, a gravel bed

river in south Albania. The Vjosa is one of the last untouched braided rivers in Europe with a notable ecological valuable to be protected. In the basin currently, there are plans for hydropower development that pose a serious threat to this valuable ecosystem.
We applied CASCADE on the Vjosa to assess the impact on sediment transport due to alternative scenarios of hydropower development. We defined indicators for sediment connectivity alterations and hydropower production and adopted them in a multi-objective analysis to find optimal dam siting. We validated the model using spatially distributed information on surficial grain size throughout the network, manually surveyed in the field. Furthermore, given the data scarce context, we performed a sensitivity analysis about sediment supply scenarios, and evaluated the robustness of the planning scenario rankings in function of this model uncertainty.
The results show that there are alternatives that guarantee around 50% of the maximum possible hydroelectric production without drastically altering the sediment transport or damaging the braided sections of the river. Usually, those portfolios rely on the construction of hydropower dams on the tributaries, that have lower impact on sediment connectivity. The sensitivity analysis shows that, while changes on hypothesized sediment supply significantly affect the estimation of sediment fluxes across the basin, the ranking of alternatives dam portfolios do not change significantly. The dam siting proposed is robust in relation to the uncertainty associated to sediment connectivity assessment.

"TRAP EFFICIENCY" LOSS OF ARTIFICIAL RESERVOIRS THROUGH A DIRECT AND INDIRECT EVALUATION OF SOIL EROSION RATE IN A SAMPLE CATCHMENT OF CENTRAL ITALY

Margherita Bufalini, margherita.bufalin@unicam.it
University of Camerino (Italy)

Sediment is an essential, integral and dynamic part of a river basin, cause a healthy river needs sediment as a source of life. On the other hand, the abundance of sediments can act as a potential sink for many hazardous chemicals and, especially in the case of artificial reservoirs, produce a long-term loss of storage capacity for reservoir operation and watershed management.
Even the European Water Framework Directive (WFD), although it does not deal specifically with sediments, clearly identify a link between sediment monitoring in a river catchment and the achievement of the WFD objective itself (good status of all European water resources by the year 2015).
The study, using different direct and indirect methodologies, wants to evaluate the sedimentation rate within a sample artificial reservoir (Le Grazie lake in central Italy) which, in the period 1952-2015, has caused a strong decreasing of the trap efficiency and a loss of over 80% of the water volume stored. Direct measurements of the lake bottom bathymetry, carried out in 2006 and 2015, and 3D reconstructions performed in a GIS environment, made it possible to calculate volume and weight of filling material and, in particular, to verify that the greatest contribution comes from a right tributary of the Chienti river (the San Rocco stream), deepened in a clayey

subbasin, and flowing directly into the lake.
The values obtained have been then compared with those coming from indirect evaluations carried out using the RUSLE (Revised Universal Soil Loss Equation) Method performed in the San Rocco subbasin.
The comparison between the two approaches made it possible to compensate for errors inherent the methods themselves (uncertainties in the direct measurements or the parameters used in the RUSLE equations) and, above all, to verify an upward trend in the sedimentation rate starting from 1952.

SEDIMENT CASCADES IN MOUNTAINOUS GLACIARIZED CATCHMENTS ANALYSED BY MEANS OF GEOMORPHOLOGICAL CONNECTIVITY

Anuschka Buter, anuschka.buter@natec.unibz.it
Free University of Bozen-Bolzano (Italy)

A high proportion of glaciated and permafrost areas in the Alps are retreating with consequent strong impacts on sediment cascades in mountainous catchments. A modelling approach, using a geographical information system (GIS) combined with an analysis based on graph theory, is applied to study the geomorphological connectivity of the partly glaciated Sulden / Solda catchment (~ 130 km2) in the area of Vinschgau / Val Venosta (Italian Alps). Firstly, a geomorphological map builds the base to analyze the spatial distribution of sediment source, transport and deposition areas. Secondly, potential connections between the geomorphological units of the map, regarding sediment transport, are studied based on topographic characteristics and visual evidences (e.g. a talus fan below a rock wall). Schematic pathways (straight lines) display different sediment transport processes, which build up a network between the central nodes of the geomorphological units. This network, drawn "by hand", is further compared to the results of a numerical simulation of a GIS tool named Gravitational Process Path (GPP) (Wichmann 2017). The model offers several modelling approaches to simulate e.g. rock fall or debris flows. The poster will present preliminary results of these initial steps of analysis. Next steps will comprise a detailed study of a further elaborated graph network regarding frequency and spatial distribution of the modelled transport

processes and their initiation, linkage and depositional zones. Future aspects of this work will include an analysis of multi-temporal digital elevation models (DEMs) using DEMs of Difference (DoDs) and flow routing algorithms to determine sediment pathways and calculate sediment delivery ratios (SDR). Additionally, the results of direct and indirect sediment transport monitoring operations will be used to qualitatively validate the simulation results and to understand temporal dynamics as well as triggering factors of sediment transport. The final aim is to obtain an integrated comprehension of the functioning of the sediment cascade in the studied catchment to be able to outline sediment connectivity hotspots, spatially and temporally.

DYNAMIC SEDIMENT CONNECTIVITY IN ALPINE CATCHMENTS AS A TOOL FOR SEDIMENT MANAGEMENT AT THE RIVER BASIN SCALE

Alessandro Cattapan, a.cattapan@un-ihe.org
IHE Delft Institute for Water Education (the Netherlands)

Dynamic sediment connectivity in Alpine catchments as a tool for sediment management at the river basin scale Alessandro Cattapan, Mário J. Franca, Michael McClain IHE Delft, Institute for water education, Delft, the Netherlands Any time a system is subject to changes of its internal parts or of the external factors affecting its behaviour (forcings), changes in its output are to be expected. In order to decide which changes to introduce to a system, one should be able to forecast its response. If the system at hand is a river basin, this means that one should be able to assess its response before implementing interventions or, at least one should be able to define the envelope of the system's responses so that feasible and adequate countermeasures can be prepared. Within river basins, humans require infrastructures to cover a series of water needs. The impacts of these infrastructures on natural and anthropogenic systems is difficult (if not still impossible) to estimate and therefore medium to long term effects are only partially considered in planning and management decisions.
Sediment transport in rivers is a complex process for many reasons and our ability to model it in detail is still limited therefore, in many areas of the World, the development and management of river structures rarely considers their effect at basin scale. Available morphodynamics models aim at

reproducing natural forms as consequences of changes in sediment transport rates, rather than to capture the dynamics of individual particles within the river network. These models are also often calibrated and validated using sediment transport rates measured in specific locations. These measures are affected by a number of drawbacks: they are expensive, affected by low accuracy, limited in terms of the range of sediment sizes they can collect, among others. Treating sediment transport as a flux of a continuous medium makes it difficult to associate it with individual particles' properties. Sediment come from different sources and, during their "travel" through the river network, they change in size and shape. Each sediment particle can therefore be characterised by the distance it travelled: from its entrance into the river network to its actual position on the river bed. Sediment fingerprinting techniques aim at the definition of this source-sink relationship. Theoretically, if one could know this distance for each particle, it would be possible to create a map expressing, for each river reach, the percentage of its bed sediment coming from each upstream reach. This map is the sediment connectivity of the network (Czuba and Foufoula-Georgiou 2014; Schmitt, Bizzi, and Castelletti 2016; Czuba 2018). Recent studies on abrasion claim the existence of a "universal" relation between mass loss and specific shape indices (Novák-Szabó et al. 2018).

GEOMORPHOMETRIC ASSESSMENT OF SEDIMENT CONNECTIVITY: A NEW TOOL FOR SEDIMENT MANAGEMENT

Marco Cavalli, marco.cavalli@irpi.cnr.it
Stefano Crema, stefano.crema@irpi.cnr.it
Lorenzo Marchi, lorenzo.marchi@cnr.it
Istituto di Ricerca per la Protezione Idrogeologica (Italy)

Sediment connectivity, which can be defined as the degree to which a system facilitates the transfer of sediment through itself, by means of coupling relationships between its components (Heckmann et al., 2018), has important implications for the behavior of geomorphic systems.
In recent years, sediment connectivity has become a key issue in sediment transfer processes analysis and one of the building blocks of modern geomorphology. Geomorphic coupling and connectivity play a relevant role in the assessment of sediment budget in watersheds since they reflect the contribution of different processes that can have a large spatio-temporal variability. The growing availability of high-resolution Digital Elevation Models (DEMs) offers new opportunities for the characterization of spatial patterns of sediment connectivity by enabling the quantitative modeling of sediment fluxes through geomorphometric approaches. Recently, a geomorphometric index of sediment connectivity has been developed (Cavalli et al., 2013) along with related freeware software tool (Crema and Cavalli, 2018) with the aim of characterizing connectivity patterns at the catchment scale. This index allows estimating the contribution of a given part of the catchment as a sediment source and defining sediment transfer paths. In this work, the index of connectivity is presented with a specific focus on its recent applications

in different contexts. The applications demonstrate that a reliable assessment of sediment connectivity via geomorphometric approach, especially when integrated with a sediment sources inventory, is particularly useful for giving management priorities. This is a key issue when dealing with sediment management and has important linkages with hazard assessment and in relation to priorities of intervention at the catchment scale.

LONG TERM MONITORING OF RIVER BEDLOAD FLUX IN REPRESENTATIVE SANDBED RIVERS OF THE EMILIA-ROMAGNA REGION, ITALY

Silvia Cilli, silvia.cilli@unife.it
Edoardo Grottoli, edoardo.grottoli@unife.it
Paolo Ciavola, paolo.ciavola@unife.it
Leonardo Schippa, leonardo.schippa@unife.it
University of Ferrara (Italy)
Paolo Billi, paolo.billi@alrc.tottori-u.ac.jp
IPDRE, Tottori University (Japan)

Beach preservation is fundamental for the Emilia-Romagna region since an important part of its economy is based on tourism, in particular on the coast, that is highly exploited for recreational activities during summer. In this part of the Adriatic coast, beach retreat is well known problem and several factors have worsened it in the last decades. One of the most important is the reduced rate of sediment supply. Coastal sediment budgets are controlled not only by longshore sediment transport but also by bedload influx from rivers. Unfortunately, the sediment yield of the Emilia-Romagna rivers is still undefined, except for few cases. In order to widen the dataset of river sediment supply in the whole region, bedload measurement campaigns in representative rivers were carried out by the authors in two different periods (2005-2006 and 2017 - ongoing). The research presented in this poster focuses on the Fiumi Uniti and the Savio rivers which are paradigmatic in terms of river morphodynamics and sediment supply to the coast. With their catchment areas of respectively 1540 and 645 km2, they both originate in the Northern Apennines and outflow into the Adriatic Sea south of Ravenna. The study shows sediment transport measurements in the downstream reaches of both rivers during their main floods. The field bed load data measured up to date were compared with predictions of bedload formulae,

well-known in literature, and considered suitable for the peculiar characteristics of these coastal rivers. Afterward, a gradually varied hydrodynamic model was applied to the downstream river reaches. The model was calibrated on a representative set of recorded floods and the results was used as entry parameters in the bedload transport formulae. Moreover, given the short duration of the field campaigns, a thirteen-year discharge data analysis and sediment yield assessment was carried out. Among the bedload equations developed for sandy and sand-gravel mixtures of sediments, Martin's (2005) and Bagnold (1980) criteria best approximated the field data. The multidisciplinary approach adopted in this study, combining classical hydrological and hydraulic analyses with field measurements, is mainly oriented to define the long term sediment supply from the two study rivers within a new perspective toward a regional approach to better predict the mean annual river sediment supply to the local coast.

DOWNSTREAM MORPHOLOGICAL EFFECTS OF SEDIMENT BYPASS TUNNEL OPERATIONS: 1D NUMERICAL STUDY

Matteo Facchini, matteo.facchini@unitn.it
University of Trento (Italy)

Sediment Bypass Tunnels (SBT) have been proven to be an effective countermeasure to reservoir sedimentation, but their morphological effects on the downstream reach are still poorly investigated. The final goal of this work is to quantify the morphological changes in terms of riverbed slope and grain size distribution (GSD) induced by realistic SBT operations.
Possible SBT-release scenarios are obtained starting from the observation that to properly work a SBT must have a higher sediment transport capacity than the river flowing in the reservoir. Therefore, given the slope and the GSD of the upstream river reach, the relationship between the water and the bedload discharge can be calculated for the upstream river reach and the SBT. SBTs are usually designed according to a given water discharge value, which identifies the maximum bedload discharge that can be carried by the SBT. The minimum bedload discharge transported by the tunnel corresponds to the water discharge value for which the SBT is first put in operation. Then, we can identify four possible scenarios: i) scenario 1 (no SBT operation), for which the SBT is not operated and bedload carried by the upstream river is all stored in the reservoir; ii) scenario 2 (SBT design range), for which the entire amount of bedload coming from upstream is diverted downstream by the SBT; iii) scenario 3 (large floods),

for which the water discharge flowing through the SBT is the maximum possible and the surplus can be either stored in the reservoir or conveyed through the dam outlets, both entirely or partially; the bedload discharge is smaller or equal to the maximum possible; iv) scenario 4 (very large floods), for which both water and bedload discharge correspond to the SBT transport capacity and extra water is released from the dam. To quantify the downstream changes in riverbed slope and GSD due to SBT-releases, we run numerical simulations with BASEMENT (www.basement.ethz.ch). We consider a simplified configuration, i.e. a straight channel with rectangular cross-section, non-erodible walls and constant slope. At the upstream boundary a hydrograph and a sedimentograph are imposed according to the possible SBT-release scenarios. They vary sympathetically in time and are cycled until morphological equilibrium is attained. A typical gravel bed river GSD is fed at the upstream boundary. Results at the event-scale show that riverbed level lags behind its composition, which is reworked within the first one to five SBT operations in the design range. Concerning riverbed level, a pulse dynamic is observed if bedload-free operations are alternated with bedload-laden ones. In fact, bedload-free releases favor pulses advection over dispersion. Concerning riverbed GSD, SBT operations have the power to break the armored layer present on the surface and each SBT release causes an oscillation of the surface composition.

2D MODELING OF GLACIER-FED GRAVEL-BED RIVERS

The main aim of this work is to study the effect of cyclic fluctuations of water discharge and sediment feed rate on the formation and evolution of river bedforms in glacier-fed gravel-bed rivers. The coupled effect of cyclic synchronous water and sediment input has not been investigated in detail, particularly in the case of heterogeneous sediments. Here we use the 2D module of the numerical model implemented in BASEMENT (www.basement.ethz.ch). We consider a simplified configuration, i.e. a straight channel with rectangular cross-section, non-erodible walls and constant initial slope. At the upstream boundary, a hydrograph and a sedimentograph are imposed and vary sympathetically in time. An admixture of sediment grain-sizes composes the initial riverbed surface texture, the sediment feed, and the sediment transport, which occurs only as bedload.

The model setup and calibration is supported by and validated against laboratory experiments, which provided accurate data on bed topography, surface texture, and bedload flux.

2D modeling with grain sorting requires the calibration of several model parameters, whose effect on the final bed morphology are not well known in the literature. Preliminary results showed that grainsize distribution discretization, bedload transport equation and gravitational transport, wet and dry collapse and deposit angles are crucial parameters.

The calibrated model is used to reproduce the formation and evolution of bedforms, and to describe their effect on sediment dynamics and riverbed texture.

Numerical analyses can be performed on long time- and spatial-scale, extending lab analysis results and providing quantitative estimates that may be used in assessing potential future impacts of glacier melting.

RIVER SEDIMENT TRANSPORT MONITORING BY MEANS OF H-ADCP

Massimo Guerrero, massimo.guerrero@unibo.it
Rui Aleixo, rui.aleixo@unibo.it
University of Bologna (Italy)
Nils Ruther, nils.ruther@ntnu.no
NTNU, Norwegian University of Science and Technology (Norway)

Monitoring stations in rivers and water courses are an important mean to obtain critical data about the different variables that play a role in the hydrodynamics and ecological processes. This is especially true during rough weather conditions when direct observations are not possible and even dangerous. A technique to determine the suspended sediment transport by means of fixed ADCPs at the side of a river channel (i.e., H-ADCP) is here presented. This technique relies on the Channel Master by Teledyne-RDI which continuously measures water velocity and echo intensity profiles along an horizontal alignment, these measurements are then transmitted to a remote server via GSM. In addition the proposed technique is based on an acoustic method to investigate poorly sorted sediment in the spectrum ranging from clay to fine sand. This combines the measurement of sound attenuation and backscatter to determine instrumental sensitivity to actual matter suspended in the horizontal alignment, thus relaxing the need of frequent calibrations to account for changes in the backscatter return not ascribable to a change in suspended sediment concentration, SSC. Last but not least a Matlab GUI was developed for the acoustic method implementation-validation and its coupling with discharge assessment using water velocity profiles from the Channel Master. The overall technique was applied in two very

different case studies: i) the Devoll river in Albania that is a typical mountain stream with flow velocity and SSC larger than 5 m/s and 10 g/l during floods, respectively, in this case the monitoring serves hydropower industry; ii) the Secchia river where the observed peaks were close to 1.5 m/s and 2 g/l, this is the case of an embanked stream flowing in one of the most populous and heavily built areas of Italy where the monitoring station serves the prediction of sediments deposition and erosion close to existing infrastructures (e.g., bridge and levee). The proposed technique proved to work properly in both case studies eventually enlarging the Channel Master capabilities to river sediment transport monitoring.

SEDIMENTATION AND HYDROPOWER: A DETAILED IMPACT ANALYSIS OF CHANGING SEDIMENT REGIME IN CAMBODIAN RIVERS

Mohit Kaura, mohitkaura@mail.usf.edu
University of South Florida (USA)

Hydropower relies on protection of watersheds to regulate water and sediment yields. Deforestation accelerates the rate of soil erosion, thereby increasing the amount of river sediments heading to the dam's reservoir, decreasing the longevity of the dam. In Cambodia in particular, recent deforestation rates are among the largest on the planet, and forests are expected to disappear within the lifespan of proposed dams. The cost of protecting and restoring forested watersheds can be considered as an annual investment towards sustainable reservoir management and hydropower generation. A modeling framework is developed to estimate the sediment accumulation in reservoirs from deforestation-driven soil erosion. Associated power generation loss is then calculated, and by relating it to current electricity tariffs, the annualized and present monetary value associated with the benefits of forest conservation to hydropower are estimated. This framework is applied to four large hydropower proposed dams in Cambodia. With an ongoing average deforestation rate of 0.85-1.65% in the past 5 years, some reservoir watersheds could lose all forest cover in the coming 40-75 years. This could increase the current sediment yield up by 1.5-1.8 times resulting in acceleration of reservoir filling with sediments, which depending on their size, could lose up to 60-100% of their storage capacity over a period of 120

years. This would incur additional sediment removal costs to the hydropower industry, which could be reduced through investments in forest conservation and restoration, potentially financed via a payments for ecosystem services scheme. The estimated net present values of power loss in Stung Sen, Pursat-I, Battambang-I and Battambang were US $0, $3.11, $6.76 and $1.1 million respectively. The modeling tool is designed to be generic and transferable to other rivers globally where hydropower development is accelerating.

MODEL OF BACKWATER-INDUCED ABIOTIC–BIOTIC INTERACTIONS IN GRAVEL-BED RIVER

Maciej Liro, maciej.liro@Gmail.com
Polish Academy of Sciences (Poland)

Nowadays global water and sediment transfer by rivers is disturbed by more than 58,000 large dams. Up to now, their downstream hydromorphological, sedimentological and ecological effects as well as documented delta development and reservoir siltation were analyzed. Recently some works have analyzed Carpathian river's sections in so-called backwater zone upstream of a reservoirs [1]. In this distinct zone, the fluctuating water inundation from reservoir facilitates sediments deposition and leads to significant morphological changes, which potentially interact with riparian vegetation development and other biotic components of fluvial systems and human life in this zone. All the above-mentioned adjustments should potentially influence river biogeomorphological functioning in backwater zone but there is lack of works which might be used for predictions of these adjustments.

To fill this gap, I synthesize the existing state-of-the-art of research on upstream effects of dam reservoirs on alluvial rivers into a conceptual model of backwater-induced abiotic–biotic interactions in river valley. This model indicates that backwater-induced changes in flow and sediment dynamics create conditions favouring seed germination and plant growth and decrease plant mortality during floods, but in contrast prolonged water inundation in this zone eliminates

plants non-resistant to water stress. This should significantly modify the trajectories of fluvial biogeomorphic succession cycles and spatial distribution and the extent of zones of vegetation–hydromorphology interactions in a river corridor. For example, the first stage of biogeomorphic succession (geomorphic phase) may be inhibited because of reduced flow energy in this channel section reflecting lower channel slope and the direct effects of water inundation by the reservoir. In turn, further stages of the biogeomorphic succession (pioneer, biogeomorphic, ecological) should be favoured in the backwater. It may be expected that riparian plants intolerant to frequent and deep inundation will be pushed to the upper limit of maximal backwater inundation, which will significantly change the initial structure of riparian vegetation mosaic to less diverse. The habitats left by these inundation-intolerant species will be quickly occupied by more water-resistant plants, such as willow species. Spatial distribution and the extent of zones of vegetation–hydromorphology interactions in a river corridor reflect climatic, moisture availability, fluvial disturbance conditions, and the degree of river corridor confinement in a given part of fluvial systems. Based on the presented model I hypothesize that in backwater zone, regularly inundated zones 3 and 4 will be extended because of the higher frequency and magnitude of water inundation. Zone 5, where inundation is absent or extremely rare, will be pushed to a higher position on the valley floor, around the maximum level of water fluctuations in the reservoir. The presented synthesis implies that the fluctuating backwater zone on mountain river appears to be very interesting, but rarely studied part of the fluvial system. Biogeomorphic evolution of typical gravel-bed river in this section should contrast with those observed in free-flowing reaches

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MONITORING SOURCE AREAS AND SEDIMENT DELIVERY IN AN ALPINE MOUNTAIN BASIN

Lorenzo Picco, lorenzo.picco@unipd.it
Daniele Cazzador Oss, daniele.osscazzador@studenti.unipd.it
Riccardo Rainato, riccardo.rainato@unipd.it
Mario Aristide Lenzi, marioaristide.lenzi@unipd.it
Università degli Studi di Padova (Italy)
Universidad Austral de Chile, Valdivia (Chile)
Universidad Austral de Chile, RINA (Chile)

Recently, the attention on connectivity between hillslopes and channel network has increased. The coupling relationships between sediment source areas and channel network is mainly analyzed using numerical models, and GIS modelling. The main aim of this work is to propose a methodological approach able to increase the comprehension of sediment delivery processes in an alpine basin. Specifically, field investigations were carried out to detect the sediment transfer from source areas to the channel network. Different variables as roughness, grain size, and rainfall were considered in order to assess the relative influence on sediment mobility along the Rio Cordon basin (Eastern Italian Dolomites). To better characterize the source areas, five different typologies were considered, and high resolution DEMs (0.05 m cell) were obtained using UAV technology. Moreover, twelve sediment source areas were investigated, and 242 tracers were installed to analyse sediment mobility from these areas and, potentially, along the hillslopes. Rainfall datasets were collected from three rain gauging stations disposed into the basin. After a rainfall event, every source area were monitored to detect tracers displacement. Although the source areas monitored did not show connectivity with channel network, considerable movements were observed. Specifically, six source areas exhibited sediment movements, with mobilized tracers

ranging between 25 and 130 mm (b-axes). Longer travel distance were observed along the debris flow channels (up to 19 m), while considering the number of elements mobilized, the slides were the more active typology of source area (34.4% of tracers mobilized). Roughness index of source areas is positive correlated to the transport magnitude. Rainfall intensity highlighted different pattern between the upper and lower part of the basin, showing major intensity for events shorter than 3 hours in the upstream part. However, data collected did not shown clear relationship with the mobility of tracers. This methodological approach may help to increase the knowledge about the sediment transfer processes in alpine basins, focusing on threshold conditions of the source areas, and on the sediment mobility acting on them. Despite these preliminary results, this evidence can help to better comprehend the degree of (dis)connectivity acting in the study site.

A NEW EXCEPTIONAL EVENT IN THE RIO CORDON BASIN: NEW CHALLENGES ARE COMING AFTER THE OCTOBER 2018 FLOOD

Riccardo Rainato, riccardo.rainato@unipd.it
Lorenzo Picco, lorenzo.picco@unipd.it
Daniele Cazzador Oss, daniele.osscazzador@studenti.unipd.it
Lorenzo Martini, lorenzo martini@unipd.it
Mario Aristide Lenzi, marioaristide.lenzi@unipd.it
Università degli Studi di Padova (Italy)
Universidad Austral de Chile, Valdivia (Chile)
Universidad Austral de Chile, RINA (Chile)

At the end of October 2018, intensive and persistent rainfalls affected the northeastern Italy with values higher than 300 mm in 3 days recorded in some watershed. Such precipitation caused windthrows, floods, debris flows and sediment- and wood-laden events, causing several damages to the mountain area. The Rio Cordon is a small alpine basin (5 km2) located in the Dolomites, with an elevation range between 1763 and 2763 m a.s.l. Since 1986, the catchment is equipped with a permanent monitoring station, which continuously measures the water and sediment fluxes as well the climatic conditions. This structure was realized by a collaboration between Veneto Region (Experimental Centre of Arabba) and University of Padova (TeSAF Department) and it is currently managed by ARPA Veneto. On the long-term, the monitoring program maintained active in the Rio Cordon basin permitted to investigate the climatic trends, the runoff processes, the sediment dynamics and the landform evolution. In terms of sediment transport, 31 flood events were recorded in the period 1986-2017. The highest magnitude was exhibited by the September 1994 event: in late summer, intense precipitations triggered a flood with a peak of discharge (Qpeak) equal to 10.40 m3 s-1 and the transport of 900 m3 of bedload material to the monitoring station. This flood deeply influenced the

catchment, modifying the channel network and creating several new sediment source areas throughout the watershed. Consequently, an alteration of the sediment dynamics was appreciated on the long-term, by increasing the transport efficiency for about a decade. In light of this, the event of September 1994 was defined as an "exceptional event". On October 29, 2018, a new exceptional flood occurred in the Rio Cordon basin and, in light of the first field observations, the magnitude seems to be higher than the September 1994 event. Between October, 27 and October, 29 a rainfall amount of 331 mm were recorded, which corresponds approximately to the 30% of average annual precipitation. Similarly to what observed in 1994, several source areas were reactivated and new ones were developed, in particular in the lower part of the catchment. Qpeak is to be estimated but the field evidences seems to suggest that could be higher than the 1994-value. In terms of bedload magnitude, the October 2018 event transported downstream about 5000 m3 of coarse material, causing the partial burial of the monitoring station. The main channel shows significant geomorphic changes with large lateral erosions and, in turn, a massive wood recruitment. Also, the bedforms were strongly modified and an evident incision of the channel can be observable in many reaches, suggesting the removal of the existing armour layer. These preliminary observations suggest that the October 2018 flood deeply altered the Rio Cordon basin. In this sense, the next research activities will be focused on the characterization of the climatic and hydrological conditions of the event as well the description of the sediment dynamics occurred. Hence, the monitoring activities will be aimed even to investigate these dynamics in the near future, as consequence of the new conditions developed.

THE ROLE OF HYDROGRAPHS ON SEDIMENT TRANSPORT AND BED MICROFORMS FORMATION

Diego Ravazzolo, diravazzolo@uc.cl
Pontificia Universidad Católica de Chile (Chile)

Sediment dynamics under unsteady flow condition are still unclear and poorly investigated. Field studies showed that during the passage of a flood, the bed load movement, the suspended load distribution as well as the river processes are different from those in a steady flow (i.e. with constant flow discharge over time). Increasing the knowledge of bed topography is important for the understanding of sediment transport behavior and the monitoring and protection of aquatic life. A particular bed microform is the cluster morphology. It is formed by a group of small bed particles accumulated around a larger central stone. Cluster microforms are mainly generated by the deposition of bed material and, being more stable that the surrounding bed, many studies recognized that clusters improve bed stability. Furthermore, recent field studies have focused on descriptive analysis of cluster morphologies and most of these were documented on flume experiments. The majority of experiments on bed structuring were conducted under steady flow focusing on the formation and/or disintegration of surface texture over a range of applied discharge durations. Of considerable interest is the effect of unsteadiness on bed forms during floods but nearly all of the experiments in literature with unsteady flow conditions had been focused on bed load transport.

In this study, three types of hydrographs will be analyzed to explore their effects on sediment behavior, with particular focus on bed evolution processes and on structure upon cluster microforms. In order to represent different situations of flood, a sequence of hydrographs will be simulated, taking into consideration different antecedent hydrological conditions.

Cluster microforms, bed topography and roughness evolution will be identified overtime using the stereo-photogrammetric system which is able to create a Digital Elevation Model (DEM) of the bed surface.

The study aim is to increase the knowledge about the prediction of the evolution of clusters, their geometric characteristics and their relationship with flood events, which can have dramatic effects on bed load sediment transport as well as bed stabilization.

MONITORING NETWORK FOR SEDIMENT DISCHARGE AT MOUNTAIN RIVERS IN JAPAN

Taro Uchida, uchida-t92rv@mlit.go.jp
Hiroaki Izumiyama, izumiyama-h92ta@mlit.go.jp
National Institute for Land and Infrastructure Management (Japan)

In the last few decades, several studies on surrogate monitoring technologies, including acoustic and seismic methods etc., have been used to collect data about temporal and spatial variation of sediment load in mountain river. These advanced techniques for sediment load continuous monitoring might be effective not only for scientific issues, but also for the assessment of the watershed conditions. The monitoring data of sediment load should give us fundamental information for land management.

According to these back grounds, we installed around 80 observation stations for sediment discharge at mountain rivers in Japan since 2011. We commonly used Japanese pipe hydrophone (Japanese pipe microphone) system for bedload monitoring and turbidity meter for fine suspended sediment monitoring.

We developed calibration method "IHP method" for Japanese pipe hydrophone We also conducted direct sampling using slot sampler and bucket at several sites to validate our calibration method. Still we have several technical problems about monitoring method, monitoring devices and data calibration method. For example, our monitoring devices were often broken at relatively steep channels due to hit of relatively large boulders. Also, we have to evaluate lateral distribution of bedload and vertical distribution of suspended sediment.

Although we have to improve our monitoring methods, we compiled monitoring data and published “Data note for Sediment discharge and hydrologic observation at mountain river of Japan”. Then, several new findings are obtained through analysis of this data note. We believe this data note will contribute to further understanding of sediment dynamics in mountain rivers and development of monitoring methods for watershed conditions.

SEDIMENT DYNAMICS IN GLACIER-FED RIVERS

Matilde Welber, matilde.welber@unitn.it
University of Trento (Italy)

In glacier-fed rivers, daily and seasonal fluctuations of water and sediment input exert a strong influence on sediment transport regime. In this work, we used a physical model of a gravel-bed river to investigate the magnitude, timing, and variability of bed load flux in a system subject to unsteady inputs. A straight, rectangular channel with fixed banks was built in a 25-m long laboratory flume. Three different widths were chosen to obtain a range of bed configurations (plane bed, alternate bars, wandering). Two sediment mixtures, namely a well-sorted sand and a poorly-sorted mixture, were used as bed and input material. A software-controlled feeding system provided discharge and sediment at 1-minute steps and output bed load was recorded automatically. A laser profiler and high-resolution cameras were used to acquire imagery and elevation maps of the channel bed.
For each channel configuration, the model was run firstly under steady flow conditions to characterize sediment transport over a range of discharges. Subsequently, daily fluctuations were simulated as sequences of identical, triangular hydrographs. Sediment supply at each hydrograph step was set to transport capacity. Runs were then repeated with shifted sedigraphs, in order to simulate field cases where discharge peaks lag behind bed load peaks. Bed topography was acquired at four flow stages (minimum and maximum discharge

and halfway through the rising and falling limb).
Bed load output shows significant differences within sets of identical hydrographs due to the inherent variability of sediment transport; therefore, the average response of the channel was defined as the ensemble mean of bed load output signals over each hydrograph set. Average bed load output is higher during the rising phase, resulting in a clockwise hysteresis cycle that is wider for short hydrographs. For uniform sand, hysteresis is independent from sediment supply lag, while for mixed sediment hysteresis is more pronounced for shifted sedigraphs. Poorly sorted sediment also increases the variability of output between cycles.
Moreover, spatial patterns of sediment transport were mapped on time-lapse imagery. For uniform sediment, active area displays counterclockwise hysteresis; therefore, for increasing discharge bed load flux is more intense but concentrated on a smaller area. Active area shows a more complex relationship with discharge for mixed sediment and shifted sedigraphs.
Finally, longitudinal bed profiles acquired at different hydrograph stages show aggradation/degradation cycles in the case of shifted sedigraphs, but these effects are limited to a few channel widths downstream of channel inlet.
These results suggests that flow unsteadiness has a dominant effect on sediment routing, with sediment input timing playing a secondary role in the case of sediment mixtures, while topographic effects of sediment imbalance rapidly decline with distance from sediment sources.

NOTES

SCIENTIFIC COMMITTEE

Prof. Francesco Comiti
Prof. Maurizio Righetti
Prof. Michele Larcher
Free University of Bozen-Bolzano

Faculty of Science and Technology
Universitätsplatz 5 - piazza Università, 5
Italy - 39100, Bozen-Bolzano

science.technology@unibz.it
www.unibz.it

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The Civil Protection Agency of the Autonomous Province of Bozen-Bolzano supports the event through the HyMoCARES Project. The project will contribute to enhance protection, conservation and ecological connectivity of Alpine freshwater ecosystems, as the main pressures affecting their ecological status are related to the alteration of their hydromorphological dynamics.