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Editorial

Special Issue “Fluvial geomorphology: sediment transport, river management, and extreme events at different spatial and temporal scales”

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The Special Issue on *Fluvial geomorphology: sediment transport, river management, and extreme events at different spatial and temporal scales* is a collection of scientific contributions presented at the *Fluvial Geomorphology* thematic session of the *10th IAG International Conference on Geomorphology* held in Coimbra, Portugal, 12-16 September 2022 (https://www.icg2022.eu). This session composed of 38 oral communications and 25 poster presentations from 20 different countries (Austria, Belgium, Brazil, China, Croatia, Czechia, France, India, Israel, Italy, Japan, Poland, Portugal, Romania, Russia, Slovakia, Spain, Tunisia, UK, USA) was the largest thematic session of the conference. Several major topics have been addressed, including fluvial systems in the long term, remote sensing advances, human impacts on channel forms and processes, biogeomorphology of rivers, sediment transfers and connectivity, and channel response to extreme events. The Special Issue offers a collection of thirteen selected papers illustrating not only how recent research in fluvial geomorphology has improved our understanding of fluvial forms and processes at different timescales, but also how this research field has been involved in key environmental issues related to river management and restoration, and flood hazard prevention and mitigation.

The Special Issue covers several thematic fields addressed at Coimbra, which are representative of the diversity of present-day concerns embraced by fluvial geomorphologists. The understanding of geomorphic effects of human pressures is a major objective of fluvial geomorphology, as the functioning of many fluvial systems (*sensu* Schumm, 1977) is controlled by complex interactions between natural and human drivers, which are notoriously difficult to unravel (Liébault et al., 2005; Downs and Piégay, 2019; Gregory, 2019). Humans can no more be only viewed as alteration agents of fluvial ecosystems, as many efforts are increasingly made all over the world to improve the ecological quality of river channels by restoring lost or declining geomorphic functions (Newson and Large, 2006; Dufour and Piégay, 2009; Staentzel et al., 2020; Garcia et al., 2021). Fluvial geomorphology is therefore more and more requested for supporting channel restoration designs, through studies of past morphological trajectory or physical habitats associated to specific endangered aquatic species. Another topical concern is the geomorphic response to extreme floods. Although this issue has been in the agenda for a long time, notably since the seminal work of Wolman and Miller

(1960) nuancing the importance of high-magnitude events in shaping river channels, a renewal of the subject occurs during the last decade. This can be explained by the recent occurrence of many catastrophic floods with major morphological resetting of valley floors, particularly in alpine environments, like the October 2011 flood in the Apennines (Nardi and Rinaldi, 2015), the October 2018 Vaia storm in the Dolomites (Brenna et al., 2020), or the October 2020 Storm Alex in the Southern French Alps (Piton et al., 2024). Insights coming from geomorphic studies of extreme floods are of uppermost importance for natural hazards prevention policy. Fluvial geomorphology is also commonly engaged in long-term studies of alluvial landforms. This is particularly important not only for providing validation data to landscape evolution models (Coulthard et al., 2000), but also for our understanding of sedimentary records of past disturbances of sediment supply and hydrological regimes (Starkel, 1995; Knox, 2006; Macklin et al., 2006; Anthony et al., 2014). The thirteen papers presented in the Special Issue illustrate how fluvial geomorphology have recently contributed to these different thematic fields, through recent studies encompassing timescales from a single flood event to Late Quaternary, spatial imprints from local (channel reach) to regional scales, and biophysical settings including temperate, arid and tropical environments.

Five of the papers in this Special Issue analyze the geomorphic effects of different human pressures (gravel mining, dams, weirs) and, interestingly, in contrasting climatic conditions. For example, Grodek et al. provides a detailed description of the hydrological and geomorphological changes associated with the construction of a very large dam on the Fish River (Namibia), which is a river located in a geographical context for which there have been few studies of this type. In a more methodological approach, Rabanaque et al. study the geomorphological recovery in an ephemeral Mediterranean river (Rambla de la Viuda, E Spain) after the cessation of gravel mining. They use remote sensing landform classification and machine learning algorithms to quantify reach-scale morphodynamic changes over several years. Their results suggest that some channel recovery is possible in ephemeral rivers when gravel mining ceased. Llena et al. analyzed the fluvial resilience of a wandering gravel-bed river (Upper River Cinca, South-Central Pyrenees) affected by repeated instream gravel mining and floods, during the 2014-2020 period. Main findings reveal that

topographic changes (i.e., erosion and sedimentation) and geomorphic diversity were correlated with the type of stressor, in particular human activities led to degradation and decrease in landforms variety, while floods induced aggradation and geomorphic unit diversity increase. Despite the channel recovery, the deficit in sediments resulting from gravel mining and the decreasing sediment supply from headwaters remained unresolved, and led to a reduced geomorphic diversity and, ultimately, to a significant decrease in resilience. Two other papers in this thematic field are reporting results from bedload tracing experiments with passive RFID tags dedicated to the assessment of the effect of weirs or dams on sediment continuity. The study by Rollet et al., based on a 4-yrs survey of more than 800 RFID tracers seeded in two low-energy rivers of NW France (Orne and Vire rivers), confirms a significant effect of weirs and dams on bedload transport, with not only a reduced bedload mobility in reaches influenced by transverse structures as compared to reference reaches, but also a bed coarsening downstream of investigated structures. The effect of a dam removal on bedload mobility was investigated in a gravel-bed river of the Basque Country (Leitzaran River, NW Spain) by Ibisate et al., from a 6-yrs survey of 1800 RFID tracers that have been injected by yearly seeding waves during the monitoring period. This before-after control-impact (BACI) study nicely documents a considerable increase of travel distances and bedload volumes after dam removal. These two field studies illustrate how bedload tracing can contribute to improve our understanding of human pressures on sediment continuity, and demonstrate that restoration works based on dam or weir removal can have positive effects on bedload transfers.

Two other articles in the Special Issue illustrate how geomorphological knowledge can inform and support river restoration projects. Vaessen et al. investigated the regional distribution and environment characteristics which can impact the presence of *U. crassus* in Wallonia (Belgium). The *U. crassus* is an endangered freshwater mussel species, which declined all over Europe over the last 45–60 years owing to increasing anthropogenic pressures and water pollution along with climate and land-use changes. The study underscored the predominant significance of hydro-geomorphological variables. Specific stream power had a significantly negative impact, while catchment area, contrasted high- and low-flows during the year, meadow coverage and fish richness, increased the probability of

U. crassus occurrence. On the contrary, heavy metal concentration, especially Zn, presented a negative effect. Indeed, past mining activities in Wallonia were mainly responsible for contamination of channels and overbank sediments by toxic metals. Schwendel et al. use Ground Penetrating Radar (GPR) coupled with Optical Stimulated Luminescence (OSL) dating to reconstruct the past channel pattern and evolution of the Swindale Beck valley (UK). Based on this data, they reconstructed the key stages of the evolution of river morphology and floodplain formation at Swindale. In this regard, the Swindale has undergone a trajectory of morphological change over the last 1000 years, from a braided, wandering planform to a single thread. This geomorphological trajectory can be linked to historical changes in climate and sediment supply. The river therefore appears to be relatively responsive to extrinsic change. This information is difficult to obtain from surface observations alone and this work shows the potential of such information to better assess a wide range of resilient restoration options under a changing climate.

A group of articles in the Special Issue focuses on channel responses to extreme events. Vázquez-Tarrío et al. have conducted a thorough review of the published scientific literature to date with the aim of investigating how sediment dynamics influence flood hazards. This review outlines how, despite recent advances in the scientific study of this topic, there remain important challenges for better consideration of sediment transport in flood hazard assessment. Scorpio et al. analyzed channel changes induced by an extreme storm that occurred in September 2015 in the Nure and Trebbia catchments (Northern Apennines, Italy). Authors identified morphological and hydrological factors which drove the observed channel response and investigated the dynamics of post-flood channel recovery, during 5 years following the flood event. The study highlighted the different responses to the flood between the main channels and tributaries. The flood caused modification in the island's distribution and increased multi-thread patterns. Magnitude and style for widening was related to the rainfall amount and to the morphologic characteristics of valleys and channels. Studied rivers were very sensitive to changes, even some years after the flood, as all channels and especially tributaries progressively narrowed although the widening caused by the flood had not yet been completely absorbed. The study by Liébault et al. investigated channel changes that occurred during Storm Alex

(October 2020) in two alpine valleys of SE France (Vésubie and Roya). This extreme Mediterranean rainfall episode (~500 mm of rain in 24h) generated a catastrophic flood, and the subsequent mega-formation of a braided channel along a 35 km reach in the Vésubie. The comparison of the two valleys demonstrates that glacial imprints exert a strong control on geomorphic effects of the flood, with dramatic active channel widening and aggradation observed in relatively wide valley floors related to fluvio-glacial deposits. The fuelling effect of alluvial storage is presented as a key element of the sediment cascade that explains the catastrophic channel metamorphosis observed in the Vésubie. Flood hazards related to geomorphic responses are also addressed in the paper by Brenna et al., which evaluates the effectiveness of "River Morphodynamic Corridors" for flood hazard mapping. This geomorphic approach was tested in an upland catchment of the Eastern Italian Alps (Cordevole River) that has been strongly impacted by an extreme flood in October 2018 (Vaia Storm). It is shown that observed active channel widening is well predicted by the approach, but that specific mapping procedures should be considered for small streams, where the full valley floor extent can be reoccupied by the active channel during extreme floods.

Finally, two articles look at long-term evolution of alluvial landforms. Iacobucci et al. proposed a land-surface quantitative analysis to improve the geomorphological mapping of some alluvial fans along the 50 km-long southern piedmont front of the Anti-Lebanon Mountains (Damascus Basin). Nine fans were re-mapped on the basis of the elevation of fan apex, of the conical shape of the fan surface and of the "slope-break" points between the mean slope of the fan and the adjacent valley floor. Analysis focused on the estimation of several morphometric parameters of the fans and the feeding basins, as they were considered essential to assess the influence of climatic conditions and tectonic factors on the fan-building processes. Results showed that the fan slope and the basin roughness were the most relevant parameters for defining the main transport process. Breda et al. use geomorphological, geochronological and palaeoenvironmental data to propose a model of the landscape evolution of the upper Caquetá River in the northern tropical Andes. This work is timely and relevant as tropical Andean river systems are under-represented compared to temperate regions.

The Guest Editors of this Special Issue were in charge of the peer-review process. We would like to sincerely acknowledge reviewers for their careful examination of the submitted research results, and for their constructive comments, which contribute to the high quality of the published papers. The Editor-in-Chief Achim A. Beylich is also acknowledged for his supervision of the peer-review process, and for his help during the whole editorial process, that took more time than expected. We are also very grateful to chairpersons (Tomáš Galia, Emmanuèle Gautier, Janet Hooke, Askoa Ibisate, Ronald Pöppl, Anne-Julia Rollet, and Arved Schwendel) and co-conveners (António Martins, Ekaterina Matlakhova, André Salgado, and Ana Lucía-Vela) who helped us to organize, promote, and animate the Coimbra thematic session.

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