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# Using UAS imagery to characterize grain-size distribution of braided rivers

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**ABSTRACT:** This work explores the potential of UAV imagery to map grain-size distribution (GSD) of 12 well-preserved braided reaches of the Southern French Alps and Prealps. A strong calibration curve has been developed to predict the grain-size from photogrammetric point clouds. Grain-size calibration has been obtained using 129 close-range photos of 1 m<sup>2</sup> homogeneous grain-sizes patches computed on Digital Grain Size (Buscombe, 2013). The  $D_{50}$  of each photos was then fitted with the mean roughness height (Vázquez-Tarrío et al., 2017). Distributed grain-size maps of the  $D_{50}$  can be produced by rasterizing the average surface roughness in a 1 m pixel and applying the calibration curve for each pixel. The procedure has potential for rapid and continuous GSD characterization over braided reaches. Qualitative examination of a grain-size map shows great correspondence with sedimentary mosaics visible on SfM ortho-images, even in submerged conditions. Therefore, it allows for characterizing morpho-sedimentary signatures of braided reaches, which can have important applications for management of braided rivers.

## 1 INTRODUCTION

Gravel-bed braided rivers are well known for their multithread channel network developing within a mosaic of alluvial bars. Their high morphological activity related to flood regime and sediment supply (Ashmore, 2013) causes complex sedimentary processes which results in a high heterogeneity of the grain-size distribution (GSD) within the active channel (Bluck, 1979; Ashmore, 1982; Gardner et al., 2018). High-resolution mapping of the GSD of braided rivers is of uppermost interest to produce diagnostic of aquatic habitats, to predict bedload transport and morphological changes. Wolman sampling (Wolman, 1954) is the most common field method to characterize GSD over a study reach. It is however, labor intensive, time-consuming and not really adapted to the continuous mapping of surficial grain-size (Bunte & Abt, 2001). Remote sensing can be used to bypass these disadvantages. Indeed, image-based methods allow manual and automatic extraction of grain-size at small and large scales (Carbonneau et al., 2005; Verdú et al., 2005; Buscombe, 2013). More recently, methods based on 3D point clouds have been developed for grain-size estimation. High-resolution UAV images can be used to obtain 3D Structure from Motion (SfM) photogrammetric point clouds from which grain-size proxies can be computed (Vázquez-Tarrío et al., 2017; Woodget & Austrums, 2017).

This work aims to explore GSD of 12 alpine gravel-bed braided reaches located in SE France using SfM 3D point clouds derived from high-resolution UAV imagery. It focuses on the evaluation of the performance of surface grain-size prediction model and on explorations of its application to characterize morpho-sedimentary signatures of braided rivers.

## 2 METHODOLOGY

This work is based on 12 well-preserved braided reaches of the Southern French Alps and Prealps. This set of reaches has a wide range of physical characteristics drainage areas between ~10 and

900 km<sup>2</sup>, active channel width between ~20 and ~200 m and channel slope between 0.005 and 0.04. Catchment geology combines sedimentary and crystalline domains, offering heterogeneous lithological conditions for grain-size mapping. These sites allow exploring not only a size gradient, from proximal to distal river reaches, but also a sediment supply gradient, from supply-limited to transport-limited braided channels (Liébault et al., 2013).

For each site, about 10 square plots (129 in total) of homogeneous grain-size patches in exposed and dry areas of active channels were sampled. Spray paint was used to delineate patches in order to make them easily detectable on SfM point clouds. Images of plots were shot with a DJI Mavic 2 at a low relative elevation from the ground (5-8 m). Image resolution is such that GSD is considered truncated below 2mm.

The 129 close-range images were processed with Digital Grain Size (DGS) (Buscombe, 2013). This wavelet code provides an automatic estimation of the GSD from an image. Following Chardon et al. (2020), errors related to intra-grain petrographic variations were reduced by applying a median filter with a radius equal to 5% of the largest clast on images. Correction of DGS percentiles was obtained from the manual extraction of the apparent the *a*- and *b*- axes for at least 100 particles. This was done with ImageJ for 44 plots. Corrected DGS percentiles were considered as pseudo ground truth data to calibrate the grain-size proxy based on the roughness height ( $R_h$ ).

For each study reach (length about 15 times the mean active channel width), an UAV equipped for RTK direct georeferencing shot nadir images with high overlaps at an elevation of 70 m above the ground. Ground Control Points were distributed homogeneously at each site and measured with a differential GPS with an accuracy of less than 5cm.

A SfM photogrammetric processing of UAV images was performed using Agisoft Metashape software. SfM point clouds were imported in CloudCompare to manually segment the sampling plots at each site and compute their  $R_h$ . This metric is defined as the distance between a given point and the best fitting plane calculated on its nearest neighbors included in a sphere of predetermined radius (Vázquez-Tarrió et al., 2017; Woodget & Austrums, 2017).

The most performing calibration curve was used to produce a distributed grain-size map of active channels for each study site. Filtered dense point clouds (i.e. removal of non-alluvial elements) were imported in CloudCompare to compute the  $R_h$ . A 1-m resolution raster of roughness was produced by computing the mean  $R_h$  value for each pixel. Finally, the calibration curve was applied on every pixel to get the corresponding grain-size percentile ( $D_{50}$ ).

### 3 RESULTS

The best grain-size calibration curve was found for the  $D_{50}$  which is a linear function of the mean  $R_h$  with  $R^2 = 0.83$  (Figure 1). The independent error of prediction (Jackknife cross-validation) is equal to 5 mm, which corresponds to 14.4 % of the mean  $D_{50}$  computed for the 129 plots.

The calibration curve was used to map the active channel GSD at a 1-m resolution to extract the surficial GSD for each of the 12 study sites. Figure 2 presents a typical braided reach of the Arigéol stream (Southern French Prealps). It shows a very good qualitative correspondence between the SfM ortho-image (Figure 2A) and the grain-size map (Figure 2B). The sedimentological pattern of the active channel is well captured not only for exposed gravel bars, but also for submerged low-flow channels. Many types of bedforms are identifiable. The grain-size map clearly shows Alternating sequences of fine and coarse sedimentological units along the low-flow channels, which are typical of riffle-pool-bar units.

Active channel DEMs obtained with SfM photogrammetry allows to investigating topographic effects on surficial GSD within active channels. Figure 2C is a Relative Elevation Model (REM) obtained by subtracting the mean elevation of the main low-flow channel from the active channel DEM. Three geomorphic units can be distinguished within the active channel of the Arigéol when coupling GSD and REM data: (1) unit 1 corresponds to bars on the margins of the active channel, mainly composed of very coarse gravels and small cobbles, with the highest relative elevations, and sparsely occupied by shrubs; (2) unit 2 corresponds to bars occupying the center of the active channel, with a coarse GSD equivalent to unit 1, but with a lower relative elevation; (3) unit 3 corresponds to macroforms within or adjacent to the low-flow channels (riffle-pool-bar units, with bars composed of medium to coarse gravels), with the lowest relative elevations.

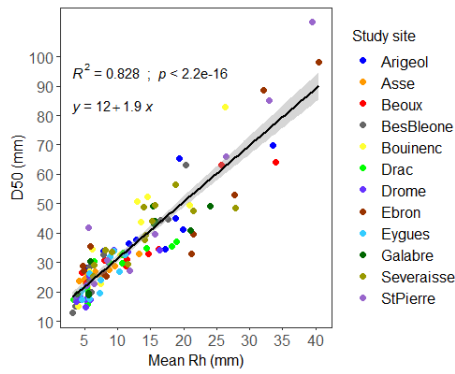


Figure 1: Calibration curve of the  $D_{50}$ -mean  $R_h$  relationship. Shaded areas correspond to the 95% confidence interval of the regression

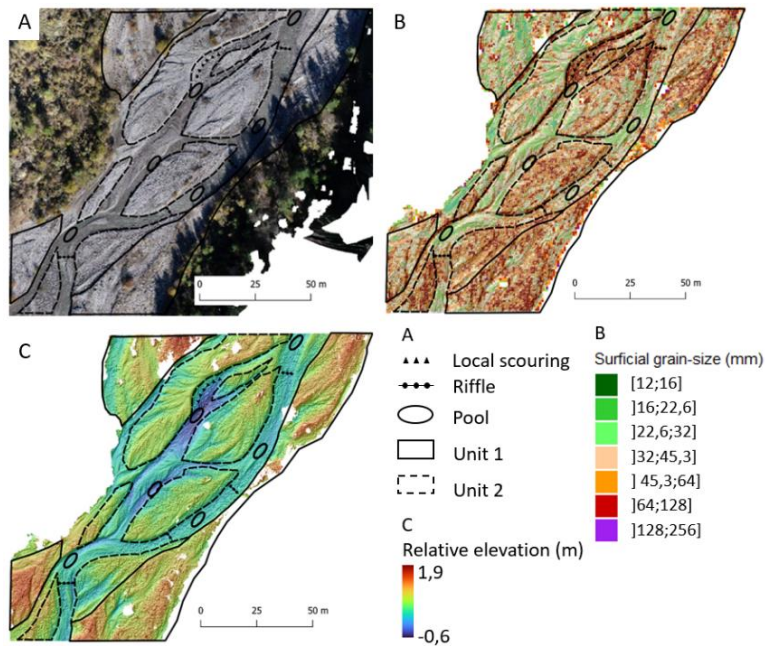


Figure 2: Morpho-sedimentary units of a typical braided reach of the Arigéol. (A) High-resolution SfM ortho-image (1.48 cm/pxl) with morphological interpretation; (B) Surficial grain-size map (1m/pxl); (C) REM (2.39 cm/pxl). Flow is from top to bottom.

#### 4 DISCUSSION & PERSPECTIVES

This multi-site field-based analysis of surficial grain-size mapping conducted in braided gravel-bed rivers of SE France confirms that the surface roughness extracted from SfM 3D data is a very good proxy of the surficial median grain-size of dry and exposed areas of active channels. The main advantage of this method, as compared to emerging models of grain segmentation based on neural networks (e.g. Lang et al., 2021; Mörtl et al., 2022), is that it is adapted to the reach-scale mapping of grain-size using high-elevation UAV images. The grain-size calibration curve shows that the median grain-size of dry and exposed areas of bars can be predicted with a 14% relative error. The qualitative agreement between braided channel sedimentary mosaics visible on ortho-images and extracted from the calibration curve shows that the grain-size patchiness of gravel-bed rivers can be efficiently captured by SfM 3D point clouds. When these sedimentary mosaics are merged with topographic signatures of the active channel (REM), it is possible to distinguish geomorphic units within the active channel. The detailed analysis of the grain-size patchiness of the Arigéol study reach shows three morpho-sedimentary units that likely inform about recent flood signatures. Fine-grained macroforms in the vicinity of the low-flow channels (unit 3), related to regular flow events occurring several times each year, are entrenched into coarser gravel

bars likely deposited during recent high-magnitude floods (units 1 and 2). This kind of grain-size pattern has been observed in several of our study sites, and it is quite different from previously reported sedimentological patterns of braided rivers, describing coarse-grained chutes and fine-grained bar-anabranch (Guerit et al., 2014). In conclusion, the grain-size mapping method presented here can efficiently be used for characterizing morpho-sedimentary signatures of braided rivers. This kind of analysis is underway for the other study sites. Our dataset will also be used for exploring sediment supply effect on the grain-size patchiness. This can have some important applications for assessing the effect of sediment supply decrease on the morphological trajectory of braided channels, which can lead to a fluvial metamorphosis towards a wandering pattern.

## REFERENCES

- Ashmore, P. E. (1982). Laboratory modelling of gravel braided stream morphology. *Earth Surface Processes and Landforms*, 7(3), 201-225. <https://doi.org/10.1002/esp.3290070301>
- Ashmore, P. (2013). 9.17 Morphology and Dynamics of Braided Rivers. In *Treatise on Geomorphology* (p. 289-312). Elsevier. <https://doi.org/10.1016/B978-0-12-374739-6.00242-6>
- Bluck, B. J. (1979). Structure of coarse grained braided stream alluvium. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 70(10-12), 181-221. <https://doi.org/10.1017/S0080456800012795>
- Bunte, K., & Abt, S. R. (2001). *Sampling surface and subsurface particle-size distributions in wadable gravel-and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring* (RMRS-GTR-74; p. RMRS-GTR-74). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. <https://doi.org/10.2737/RMRS-GTR-74>
- Buscombe, D. (2013). Transferable wavelet method for grain-size distribution from images of sediment surfaces and thin sections, and other natural granular patterns. *Sedimentology*, 60(7), 1709-1732. <https://doi.org/10.1111/sed.12049>
- Carbonneau, P. E., Bergeron, N., & Lane, S. N. (2005). Automated grain size measurements from airborne remote sensing for long profile measurements of fluvial grain sizes: *Water Resources Research*, 41(11). <https://doi.org/10.1029/2005WR003994>
- Chardon, V., Schmitt, L., Piégay, H., & Lague, D. (2020). Use of terrestrial photosieving and airborne topographic LiDAR to assess bed grain size in large rivers : A study on the Rhine River. *Earth Surface Processes and Landforms*, 45(10), 2314-2330. <https://doi.org/10.1002/esp.4882>
- Guerit, L., Barrier, L., Narteau, C., Métivier, F., Liu, Y., Lajeunesse, E., Gayer, E., Meunier, P., Malverti, L., & Ye, B. (2014). The Grain-size Patchiness of Braided Gravel-Bed Streams – example of the Urumqi River (northeast Tian Shan, China). *Advances in Geosciences*, 37, 27-39. <https://doi.org/10.5194/adgeo-37-27-2014>
- Lang, N., Irniger, A., Rozniak, A., Hunziker, R., Wegner, J. D., & Schindler, K. (2021). GRAINet : Mapping grain size distributions in river beds from UAV images with convolutional neural networks. *Hydrology and Earth System Sciences*, 25(5), 2567-2597. <https://doi.org/10.5194/hess-25-2567-2021>
- Liébault, F., Lallias-Tacon, S., Cassel, M., & Talaska, N. (2013). Long profil responses of alpine braided rivers in SE France. *River Research and Applications*, 29(10), 1253-1266. <https://doi.org/10.1002/rra.2615>
- Mörzl, C., Baratier, A., Berthet, J., Duvillard, P.-A., & De cesare, G. (2022, juin). *GALET: A deep learning image segmentation model for drone-based grain size analysis of gravel bars*. Proceedings of the 39th IAHR World Congress, Granada. <https://doi.org/10.3850/IAHR-39WC2521716X2022895>
- Vázquez-Tarrió, D., Borgniet, L., Liébault, F., & Recking, A. (2017). Using UAS optical imagery and SfM photogrammetry to characterize the surface grain size of gravel bars in a braided river (Vénéon River, French Alps). *Geomorphology*, 285, 94-105. <https://doi.org/10.1016/j.geomorph.2017.01.039>
- Verdú, J. M., Batalla, R. J., & Martínez-Casasnovas, J. A. (2005). High-resolution grain-size characterisation of gravel bars using imagery analysis and geo-statistics. *Geomorphology*, 72(1-4), 73-93. <https://doi.org/10.1016/j.geomorph.2005.04.015>
- Wolman, M. G. (1954). A method of sampling coarse river-bed material. *Transactions, American Geophysical Union*, 35(6), 951. <https://doi.org/10.1029/TR035i006p00951>
- Woodget, A. S., & Austrums, R. (2017). Subaerial gravel size measurement using topographic data derived from a UAV-SfM approach : Subaerial gravel size measurement using topographic UAV-SfM data. *Earth Surface Processes and Landforms*, 42(9), 1434-1443. <https://doi.org/10.1002/esp.4139>