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IMPROVING SEDIMENT TRANSPORT MODELLING BY A COMBINATION OF FIELD DATA AND SENSITIVITY ANALYSIS

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Traditionally, the relationship between flow rate and sediment concentration in rivers has been estimated empirically. However, the problem of empirical data collection is that it is often difficult to cover the entire range of flow rates. Especially higher flow rates are often undersampled, which might lead to an underestimation of modelled sediment transport as flood events are often associated with important erosion events. In order to overcome this limitation, the introduction of the transport capacity concept can establish a safe upper bound of this sediment transport relationship. Nevertheless, given the number of implied variables in this equation, there is a high uncertainty associated with it. In this study, we aim to reduce the uncertainty on the modelled sediment transport by constraining the relation between sediment concentration and flow rate by means of a combination of sensitivity analysis and field data.

This theory is implemented in a model that was used to simulate sediment transport in the Guadalquivir river basin, one of the most important rivers in the Mediterranean (56 978 km^2). The sediment concentration-flow rate relation was established by combining the empirical data for the lower flow domain and Yang's total load formula for the upper flow domain. In combination with data from automated gauging networks, the total annual sediment transport was calculated to be between 6.0 10^6 and 13.1 10^7 Mg year^{-1}. A global sensitivity analysis of the main parameters of Yang's equation was done to identify key data input constraints. This revealed that one of the most important parameters was the mean sediment diameter. A field sampling of flood deposits was done immediately after high flow events to determine its range.

INTRODUCTION

Soil erosion is an important problem in Mediterranean countries. The combination of intensive storm events, high slopes and cropping systems with a low vegetation cover lead to a high contribution of sediments, nutrients and other contaminants to streams. Especially in Southern Spain, this results in off-site problems such as river eutrophication, rapid sedimentation of reservoirs and flooding because of reduced hydraulic river sections due to in-channel sediment deposition. Although important progress has been made with respect to the measurement and modelling of soil erosion on agricultural fields, the sediment delivery ratio to streams and the sediment load of rivers is not well characterized. Government agencies are monitoring stream quality on an automated basis, and report sediment load, although no measurements are available for high-flow events due (i) calibration issues and (ii) automated programmed shutdown of the sensors in order to protect the equipment.

This study therefore aims to generate reliable data of sediment load and transport in the Guadalquivir basin, by a combination of field sampling, modelling and sensitivity analysis.

MATERIALS AND METHODS

The study area is the Guadalquivir basin, located in the south of Spain. Figure 1 shows the slope distribution in the catchment.

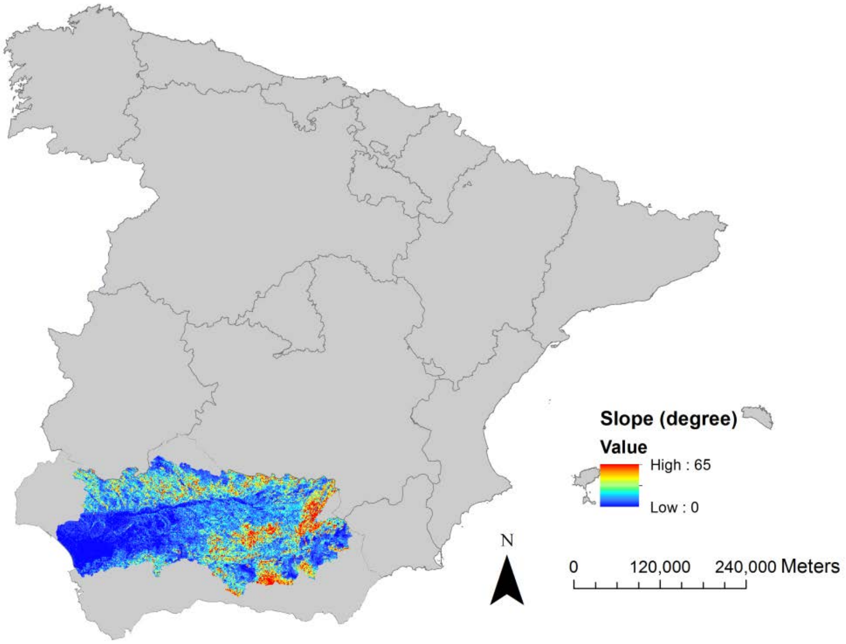

Figure 1. Location and slope map of the Guadalquivir catchment within Spain

Sediment samples were taken were taken in the middle of the catchment, near the city of Cordoba, during and after important rainstorms in the hydrological year 2012-2013. Publicly-available discharge and sediment concentration data from the SAICA network station 507 were used.

RESULTS AND DISCUSSION

The relation between discharge and sediment concentration, obtained from the automated SAICA network is shown in Figure 1. This figure clearly shows that very few measurements are available above 100 m^3s^{-1}. As such values are common, there is a clear need for additional field data, which is shown in blue in Figure 1, in order to accurately determine annual sediment transport. An exponential relation was fitted to both datasets.

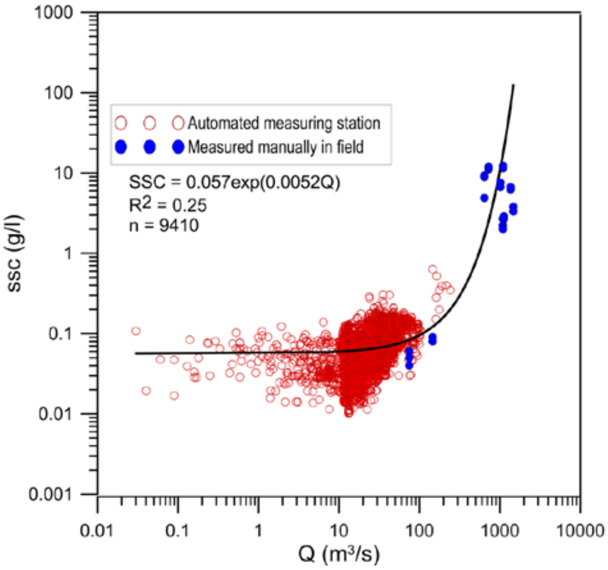

Figure 2. Relation between river discharge (Q) and sediment concentration (SSC) data, based on a combination of publicly-available automated measuring station data (red) and field campaigns (blue).

This relation however has a low coefficient of correlation (0.25) and in addition does not have a limit to sediment transport capacity, which is not in accordance with physical transport laws. Therefore, we combined this exponential regression equation with Yang's sediment transport equation for total load [1]. The resulting hybrid relation is shown in Figure 3.

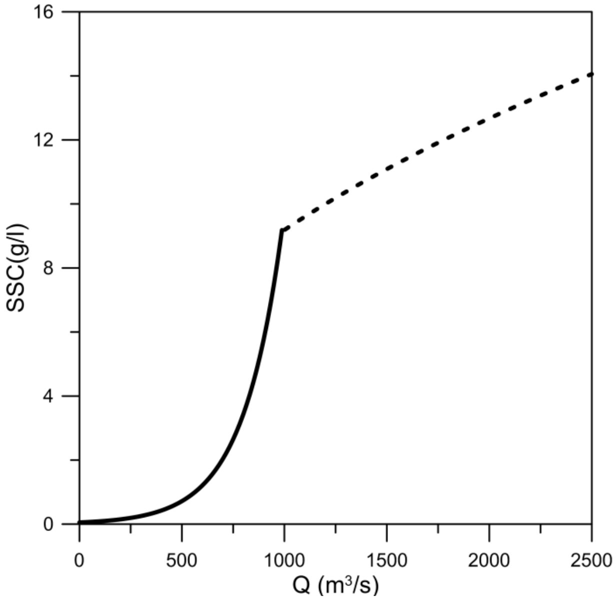

Figure 3. Hybrid relation between river discharge (Q) and sediment concentration (SSC), based on field data in the lower flow domain (solid line) and Yang's total load equation in the higher flow domain (dotted line).

With this hybrid relation and discharge data from the period 2007-2013, the temporal variability of sediment discharge could be calculated and is shown in Figure 4. It is clear that most of the sediment transport occurs during a limited number of high-flow events, as is typical in Mediterranean climates. This stresses the importance of our hybrid approach to accurately represent these events.

A global sensitivity analysis of the different parameters in Yang's equation (granulometry D50, Manning's n, river bed slope, flow geometry) was performed in order to determine the main parameters influencing the variation in the calculated sediment transport. D50 resulted to be the main influencing parameter and therefore an additional sampling was performed in order to constrain this parameter better. Figure 5 shows the variation in granulometry with depth in flood deposits of a 2012 flood.

Total annual sediment transport was calculated between 6.04 10^6 and 13.1 10^7 Mg $year^{-1}$, with a mean value of 9.98 10^6 Mg $year^{-1}$. With a catchment area of 24 704 km2 at the studied gauging station, the specific sediment contribution varies between 245 and 530 Mg km^{-2} $year^{-1}$, with a mean value of 404 Mg km^{-2} $year^{-1}$.

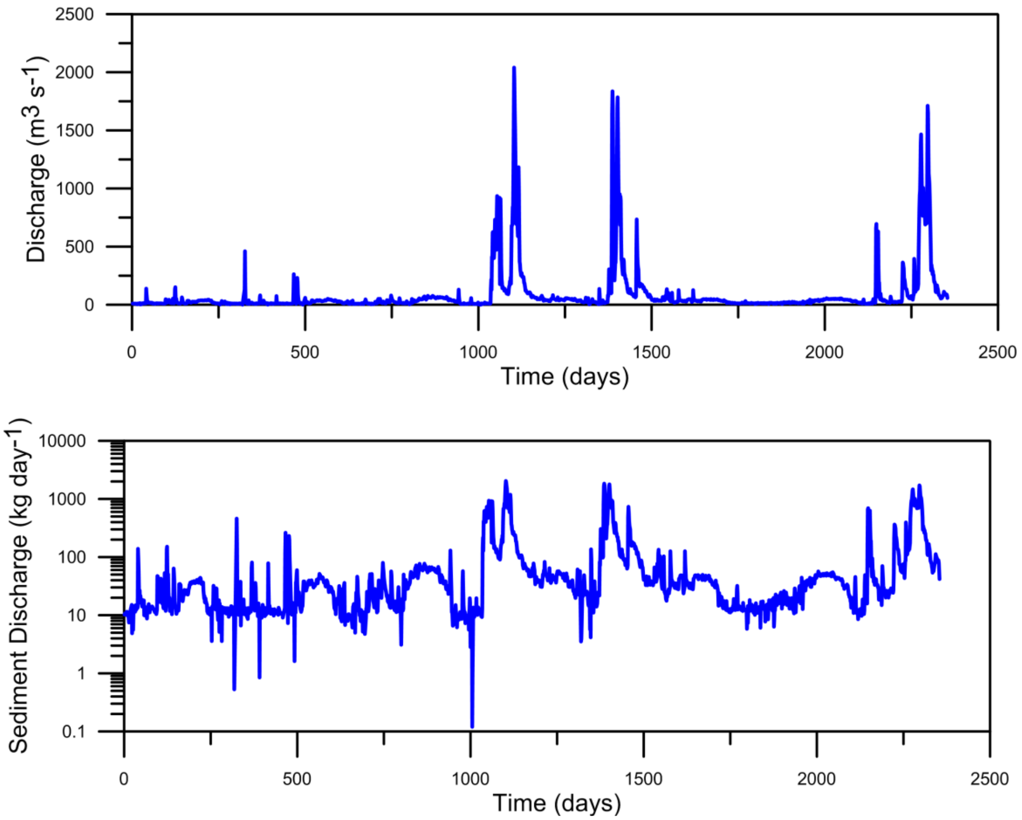

Figure 4. River discharge in the period 2007-2013 and calculated sediment discharge.

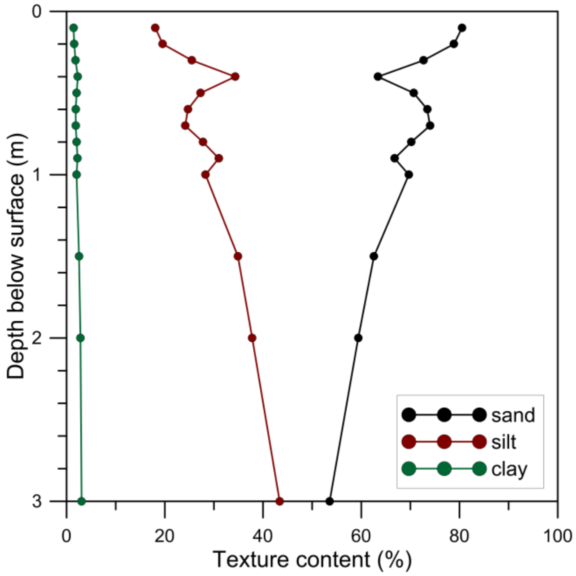

Figure 5. Texture variation in sampled flood deposits as a function of sampling depth to calculate D50.

CONCLUSIONS

A relation was established between suspended sediment concentration and discharge for the Guadalquivir river, by using a hybrid approach combining low-flow data from automated sampling stations, field sampling during high-flow events and Yang's sediment transport equation. In order to reduce uncertainty related to the calculation of this equation, D50 values were determined from flood deposits.

Finally, total annual sediment transport was calculated between 6.04 10^6 and 13.1 10^7 Mg year^{-1}, with a mean value of 9.98 10^6 Mg year^{-1}.

Acknowledgments, appendices, and references

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REFERENCES

[1] Yang,CT. 1979. Unit stream power equations for total load. J. Hydrol. 40:123-138