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# ABSTRACT
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# An integrated methodology for the riparian vegetation modelling

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ABSTRACT

We propose a methodology to calibrate a stochastic model for riparian vegetation dynamics that is based on real data. The methodology integrates various tools that are often used individually in fluvial investigations and it is here applied to the case of the Cinca river (Spain), aiming to explore how its riparian vegetation responds to changing climate conditions.

## 1. Introduction

The riparian biome is a transitional habitat that connects aquatic and terrestrial ecosystems, supporting very high biodiversity and offering a wide range of ecosystem services. However, this fundamental and fragile environment is currently threatened by anthropogenic and climate factors. Therefore, models that are able to provide a deeper understanding of the complex and interdependent processes underlying the riparian dynamics and predict future scenarios are urgently needed.

## 2. Methodology

This work aims to combine most of the fluvial approaches adopted in the literature (statistical analysis of field data, analytical and numerical modelling) into an integrated methodology to calibrate a stochastic model and provide riparian vegetation statistics for current and future scenarios.

The theoretical basis of the methodology is the minimalist eco-hydrological stochastic model CR06 (Camporeale and Ridolfi 2006). CR06 describes the dichotomic switching between biomass decay and growth in relation to the topography and the randomness of water stage fluctuations. As output, CR06 gives the analytic steady-state probability density function (pdf) of the vegetation biomass and its moments. In this model, the vegetation behaviour is parametrized by the dimensionless carrying capacity, i.e. the maximum biomass reached in optimal soil conditions, and a flood-induced decay rate. CR06 provides closed solutions for the computation of these biological parameters for very simplified geometries. However, its implementation over real fluvial environments requires a proper calibration, which we defined through a three-step methodology:

1. Collection of hydrological, biological and sediment data for the study site;
2. Definition of the water level statistics through two-dimensional hydrodynamic modelling;
3. Calibration of the biological input parameters of CR06 on the basis of the collected data.

Eventually, the calibrated CR06 can be used as a *local impact model* to investigate how the vegetation distribution varies when the hydrological conditions change.

## 3. Application to a real case

We applied the methodology to two adjacent bars of the Cinca river in Spain, within a segment approximately 9 km long. For this site, a record of the average daily flow rate since 1947 and LiDAR data acquired in 2016 were available. LiDAR data were processed with *FUSION/LDV* to obtain the site topography and the vegetation heights. In addition, a field survey was carried out on November 26th-28th, 2018 to assess the hydraulic roughness. For this purpose, 520 samples were collected through the *Wolman Pebble Count* and the grain size distribution was defined with *BaseGrain*. Data about vegetation height and diameter were also collected to regress site-specific allometric relationships for the biomass estimation.

Starting from the collected sediment and hydrological data, and the LiDAR-derived topography, we carried out two-dimensional hydrodynamic modelling. 19 simulations for different flow rates were launched with *Delft3D* obtaining the water depth distribution over the two fluvial bars. The probability of inundation was then computed and used as input for the following calibration of the biological parameters of CR06.

During the calibration phase, the whole study site was divided into cells, successively ranked in classes according to their probability of inundation. For each class, the average hydrological and topographic parameters were computed and pairs of values for the carrying capacity and decay rate were found through a least square process that optimizes the fit between theoretical and real pdfs. The calibrated decay factor satisfactorily reflects the species zonation along the riparian transects, whereas the resulting carrying capacity values appear consistent with previous field observations, where the deepening of the phreatic surface was considered the major controlling factor for the maximum plant size.

Despite the simplicity of the adopted model, the calibration gives enough information to correctly recreate the biogeography of the riparian zone. Indeed, it provides an excellent match between the map of the spatial distribution of the calibrated and the real pdf first moment (Fig. 1a-b). Numerically speaking, the overall percentage absolute difference between the two maps of the computed and real mean biomass amounts to 9.3% and 3.3%, for the first and second bar, respectively.

Finally, the calibrated model was used as a *local impact model* to investigate the consequences of mean annual daily flow rate reduction, which is expected to be 40% by 2100 in the study site (Alfieri et al., 2015). To this aim, new hydrological statistics were computed through hydrodynamic modelling and the calibrated CR06 was applied again to provide a forecast of the vegetation evolution in the new scenario. According to the results, the expected hydrological change induces a dramatic drop in the riparian biomass (Fig. 1c), meaning that the negative effect of phreatic lowering largely exceeds the beneficial reduction of flooding. Not even the adoption of adaptation strategies by the vegetation can completely mitigate this negative impact (Fig. 1d). Therefore, these results highlight the controlling role of the phreatic surface on vegetation within the study site.

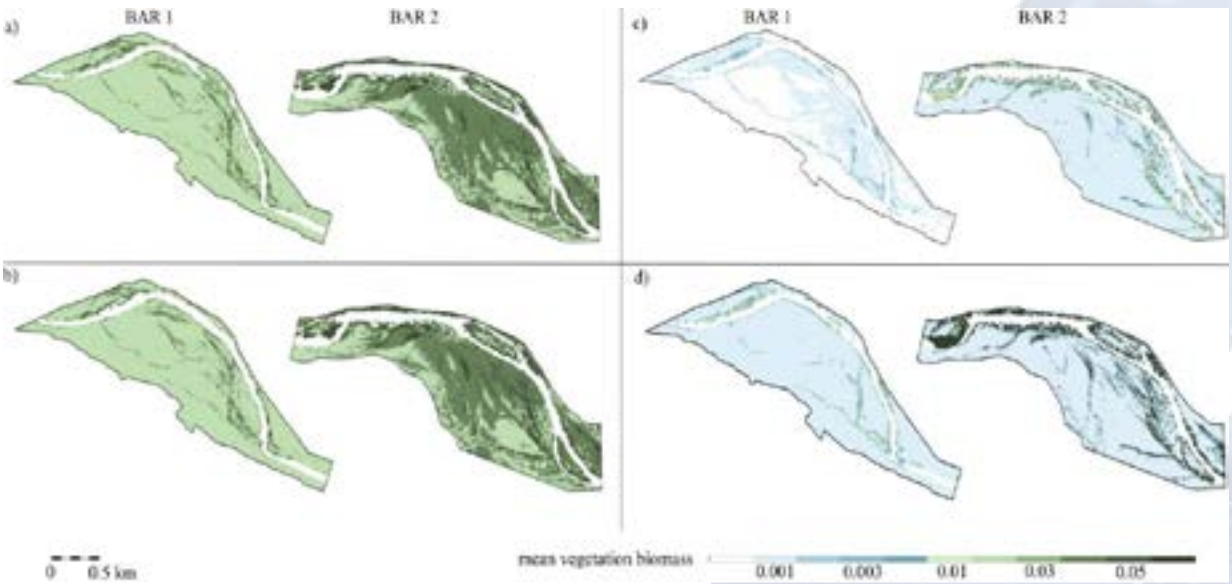


**Fig. 1.** Real (a) and computed (b) distribution of the mean vegetation biomass within the two modelled bars for the present scenario. Distribution for the future scenario with (c) and without (d) the adoption of adaptation strategies by the vegetation.

## 4. Conclusions

A methodology to calibrate the minimalist model CR06 was proposed and applied to the real case of the Cinca river. The methodology innovatively integrates different river science tools, ranging from theoretical morphodynamics and stochastic processes to geomatics and field activities. Furthermore, it effectively provides a functional description of the riparian vegetation biomass in the current hydrological conditions and forecasts potential future scenarios.

**References**

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