Using hydroscapes to maximize the benefits of riparian corridor restoration for multiple river ecosystem services

III. Benefits of river rehabilitation and synergies with other uses (flood protection, navigation, agriculture, hydropower)

"Novel Approaches to Assess and Rehabilitate Modified Rivers"

REFORM: International Conference on River and Stream Restoration, 30 June – 2 July, Wageningen, The Netherlands

José Barquín*[1], Lee Benda[2], Daniel Miller[2], Mario Álvarez-Cabria[1], Francisco J. Peñas[1], Ana Silió[1], José Manuel Ávarez-Martínez[1] & Óscar Belmar[1]

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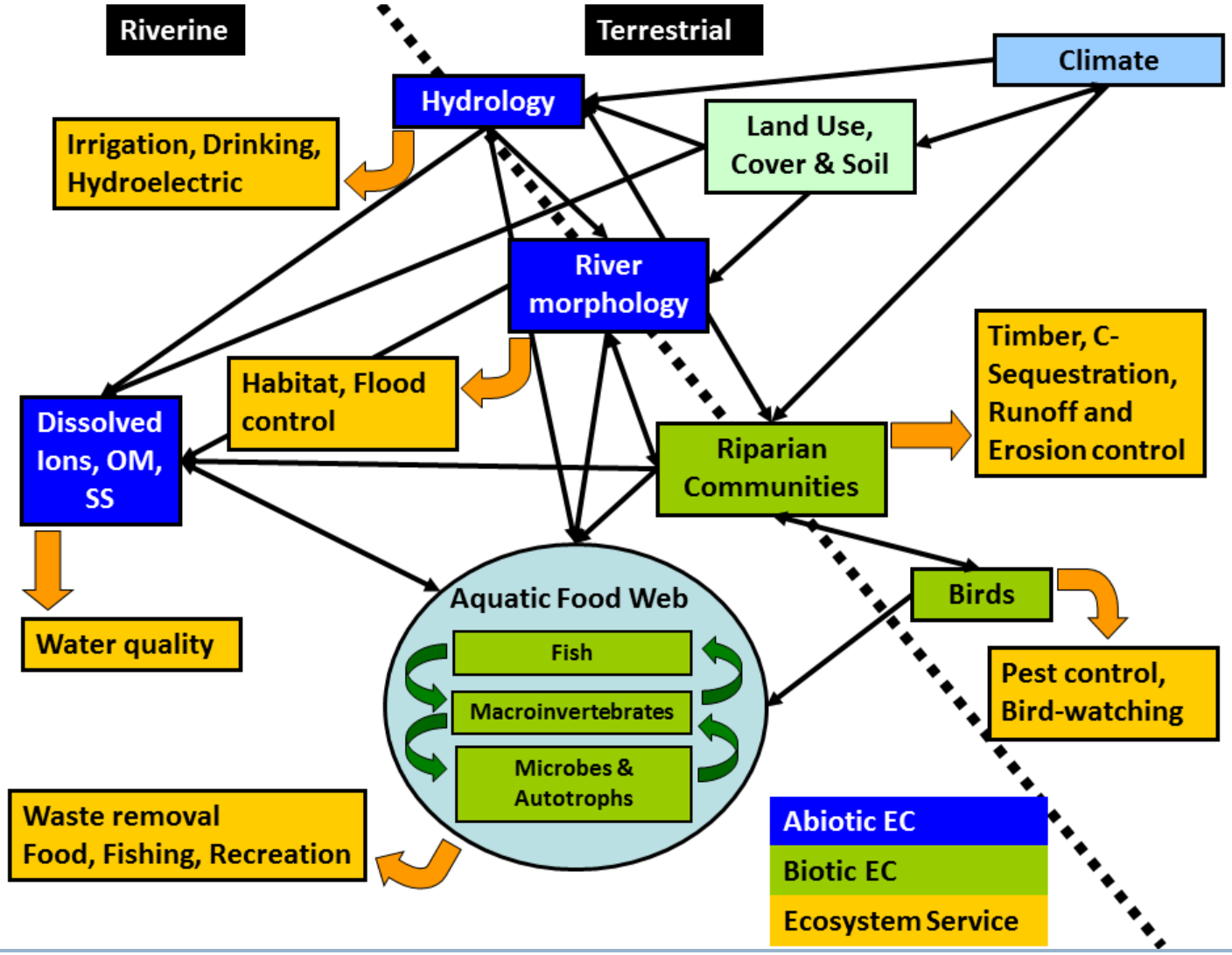
Riparian vegetation and riverine ecosystem services

The provision of riverine ecosystem services largely depend on the conservation status of riparian vegetation within the reach and in the upstream catchment.



Land use change and riparian vegetation

Despite the importance of this river ecosystem element, riparian zones have been seriously damaged all throughout the world linked to land transformation for urbanization, agriculture and pasture uses. More than 40% of Earth's land has already been converted to anthropogenic uses (Barnosky *et al*. 2012).

Low impacted reaches…

Resection and embankment for flood protection

Agriculture and pasture uses

The loss of riparian vegetation functions

Riparian woody vegetation plays key roles on river ecosystems:

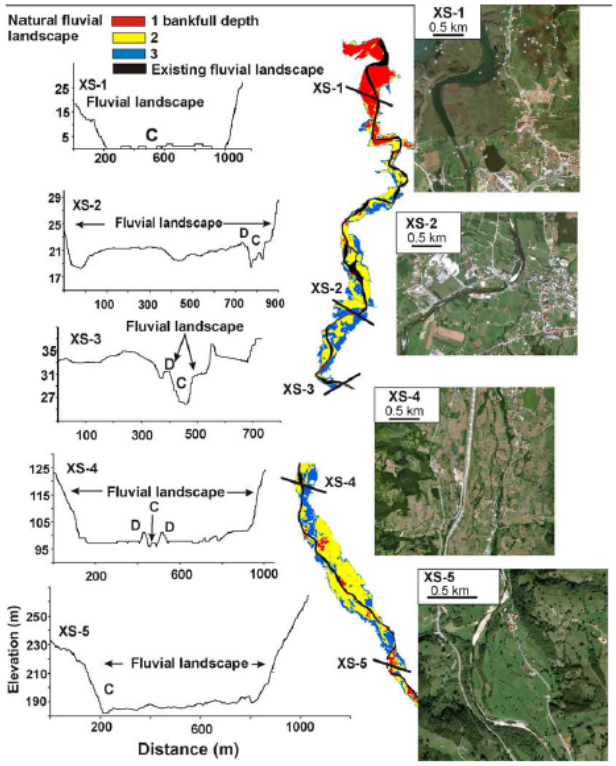
- They buffer **water temperature** and light
- They filter nutrients (e.g., **nitrate**) from runoff
- They stabilise river banks (i.e. **diminish bank erosion**)
- They provide habitat for flora and fauna (e.g., **floodplains**)
- They provide energy to the aquatic environment (organic matter and terrestrial invertebrates)

Riparian forests are also important drivers of river morpho-dynamics:

- Playing important roles on river meandering
- Providing large woody debris that influence river reach morphology
- Diminishing water velocities on large floods

River network vision for restoration…

Thus, it is important to prioritise river reaches for restoration within a whole river network (i.e. catchment), so that a larger environmental return could be obtained (i.e. multiple riverine functions).



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www.hydrol-earth-syst-sci.net/15/2995/2011/
doi:10.5194/hess-15-2995-2011

Hydrology and Earth System Sciences

Creating a catchment scale perspective for river restoration

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We have done some advances in this regard, by using synthetic river networks and virtual watersheds in order to account for river network structure (tributary confluences, tributary effects), sediment budgets, valley forms, valley side interactions and so on..

This should also include multi-criteria analysis, in which riparian vegetation functions should play a major role.

Objectives

The inclusion of riparian forest quality as another criteria within the catchment perspective for river restoration has not yet been accomplished. Moreover, its role on improving multiple functions have rarely been accomplished at large catchment scales.

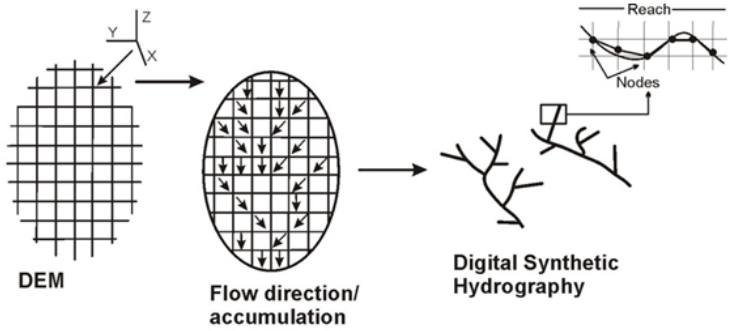
In the present study we aim to:

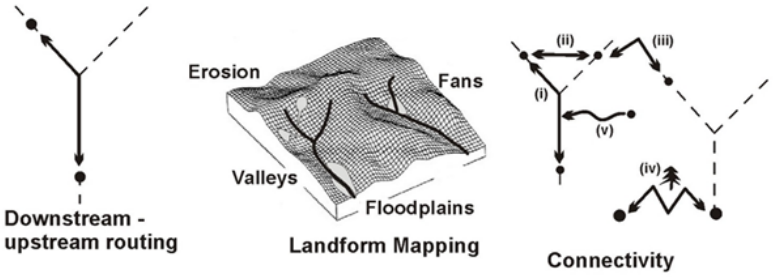
1.- Delineate riparian zones for entire river networks using hydro-geomorphological criteria

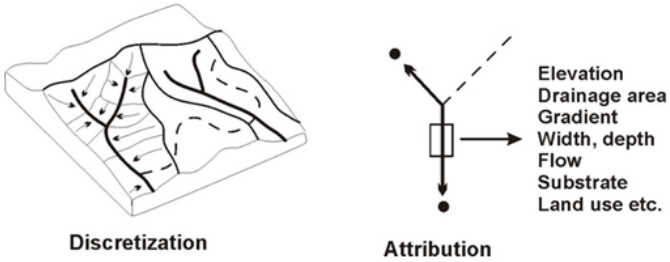
2.- Produce a riparian quality model based on land cover of woody vegetation and field observations

3.- Prioritize river reaches for riparian restoration by linking riparian quality to 4 ecosystem functions: bank erosion control, control of nitrate runoff and water temperature and enhanced floodplain habitats

Methods – Study area and Hydroscapes





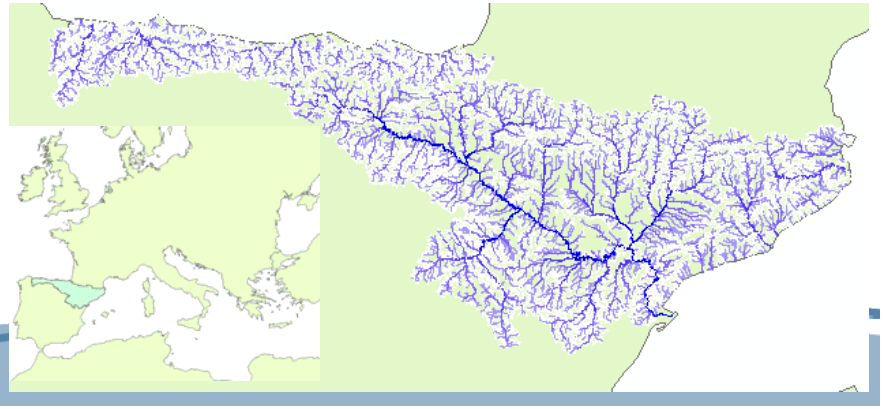


A Virtual Watershed includes synthetic river networks and the highest resolution digital elevation models, couples them together, and then adds five types of analytical capabilities, including:

1) Routing information downstream and upstream,
2) Connecting river networks to terrestrial environments,
3) Discretizing landscapes and land uses into facets of appropriate scales to identify interactions,
4) Characterizing landforms and
5) Attributing river segments with key stream and watershed information.

http://www.terrainworks.com/virtual-watersheds

We derived a Hydroscape (or Virtual Watershed) for the northern fourth of the Iberian Peninsula (Ebro river and Cantabric catchments) from a 20m DEM.



Methods - Delineation of riparian zones

The 50-yr flood has been indicated as an appropriate hydrological descriptor for riparian zones as it usually coincides with the first terrace or other upward sloping surface, and is a good indicator of high water table levels.

We derived “flood” polygons by generating a surface which intersects valley walls at a given number of BFD that best matched the 50 year flood polygon for every single river reach in the river network (Fernández *et al.*, 2012).

V-shaped valleys and gorges

Open and concave valleys

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www.hydrol-earth-syst-sci.net/16/3851/2012/
doi:10.5194/hess-16-3851-2012

Hydrology and Earth System Sciences

Quantifying the performance of automated GIS-based geomorphological approaches for riparian zone delineation using digital elevation models

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We also used this approach to delineate floodplains for entire catchments using 3*BFD criteria

Methods - Modelling Riparian Quality

Ecological Indicators 41 (2014) 165–174

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Land-use coverage as an indicator of riparian quality

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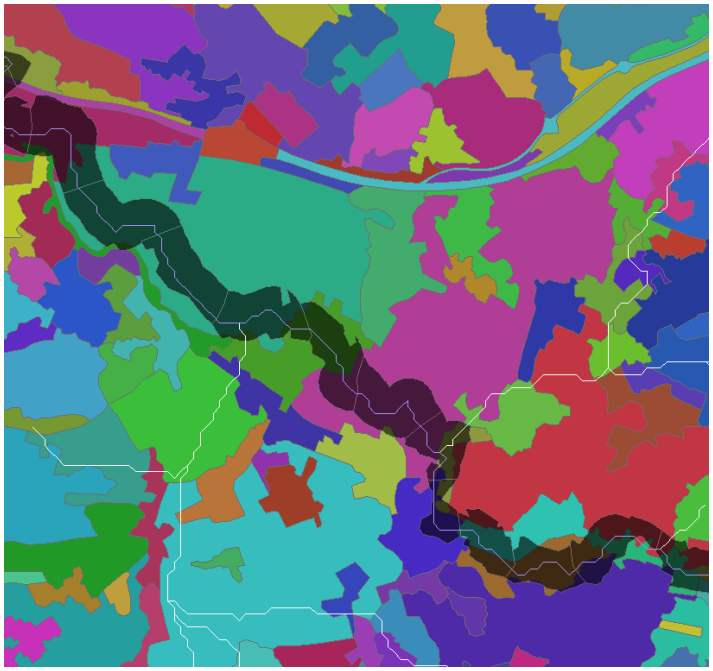
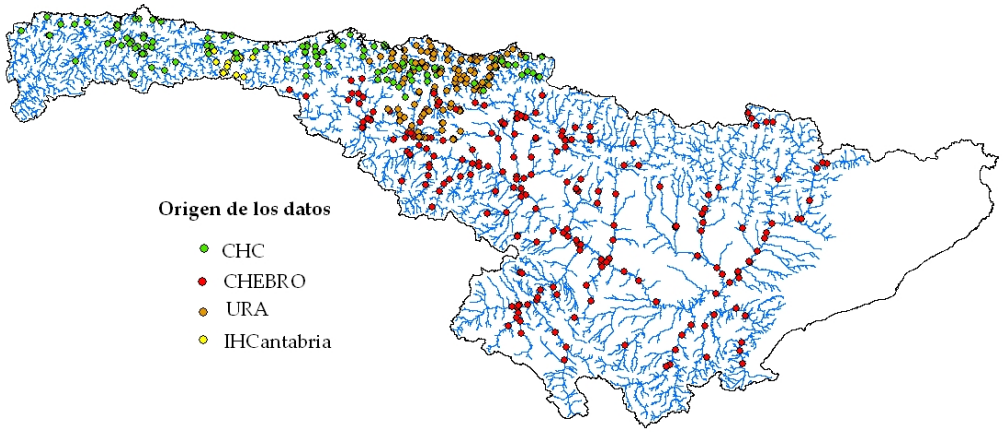


To estimate riparian quality we applied the RQI protocol (González del Tánago *et al.*, 2011) in more than 300 river reaches. This method evaluates up to 7 riparian forest characteristics using a score system (0-120).

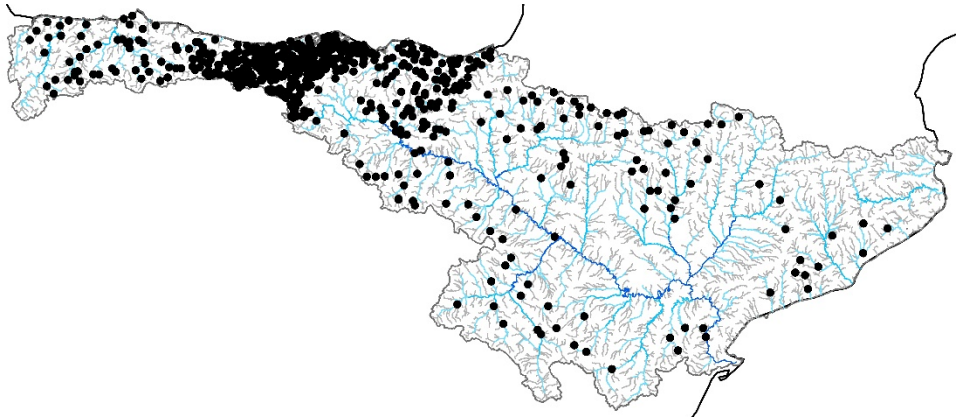
We regressed RQI scores to riparian land use composition for the above obtained riparian areas using Random Forest Models. Land use composition was obtained using the Spanish Land Cover Information System (SIOSE; Spanish coverage, 1:25,000 m scale; see Fernández *et al*., 2014. Ecological Indicators).

Methods - Modelling other characteristics

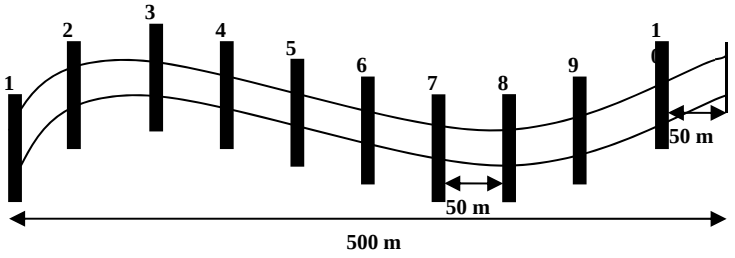
Mean annual water temperature and nitrate concentration and bank erosion were modelled using available data from the MARCE project (www.ihrivers.ihcantabria.com), and using Random Forest models with predictors obtained from the Hydroscape characterisation.



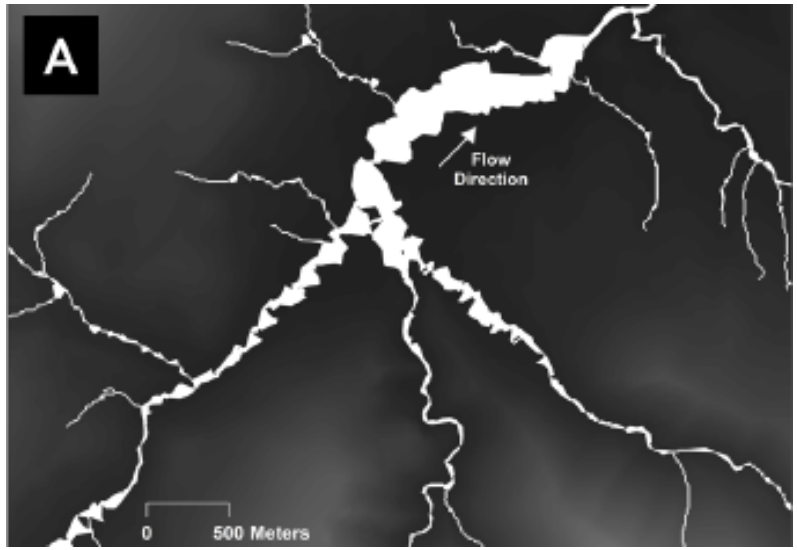
We used more than 200 sites for water quality variables with at least 8 records per year



We used more than 400 sites for bank erosion which had been characterised with the River Habitat Survey method



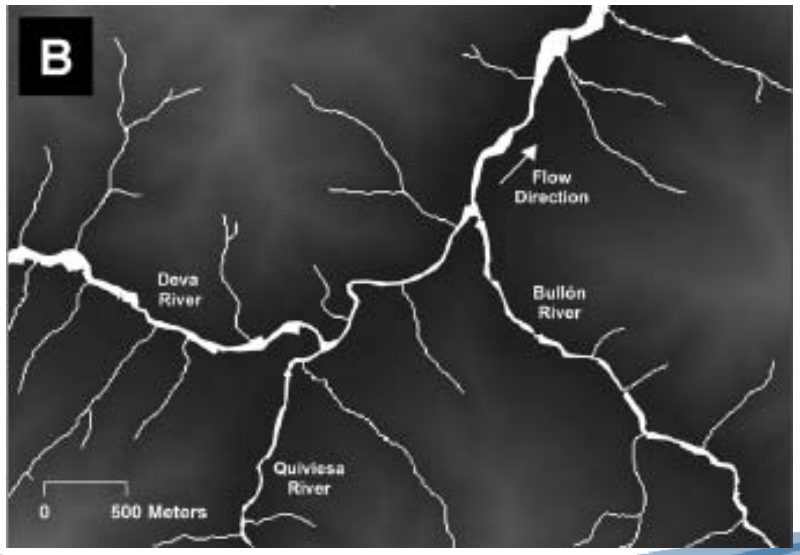
Results - Delineation of riparian zones



(A) @ a river confluence deriving in wider flood-prone areas

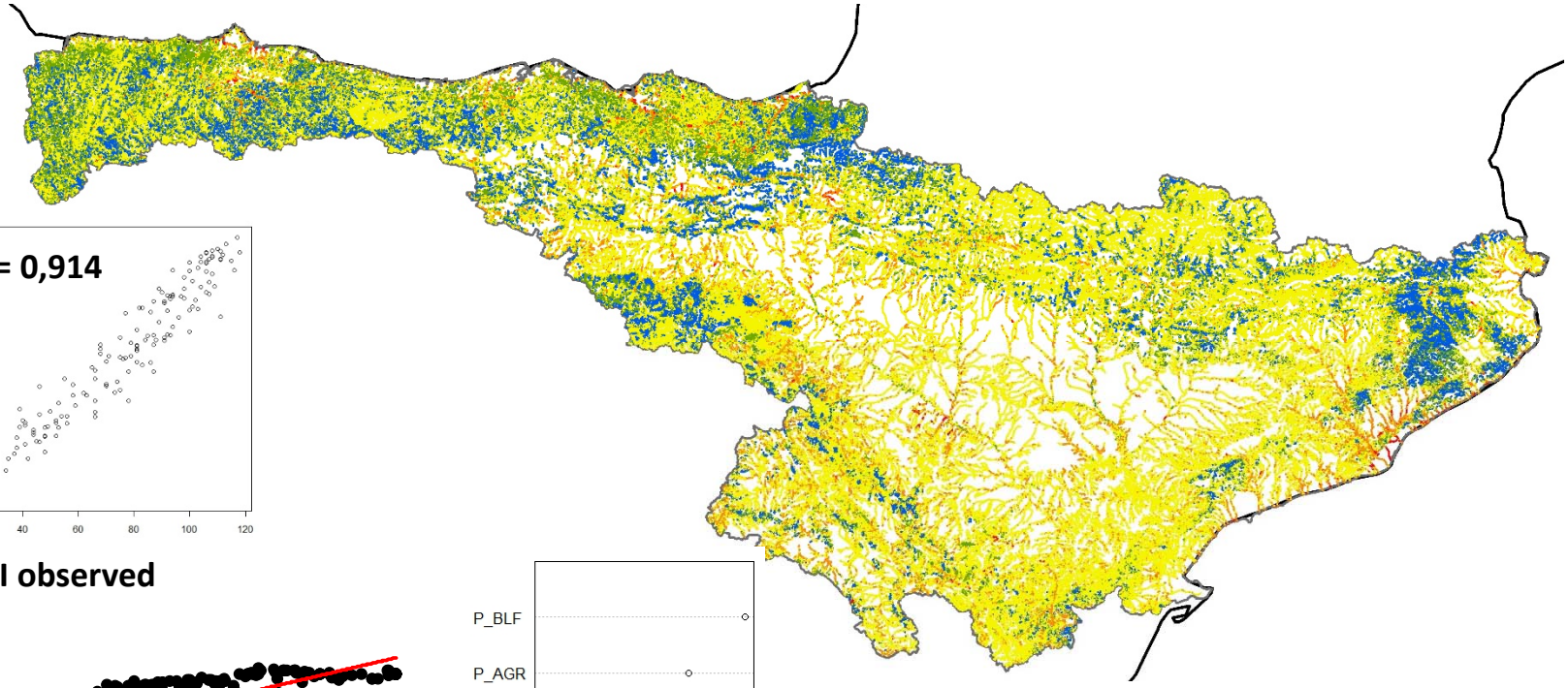
(B) @ a river confluence not deriving in wider flood-prone areas

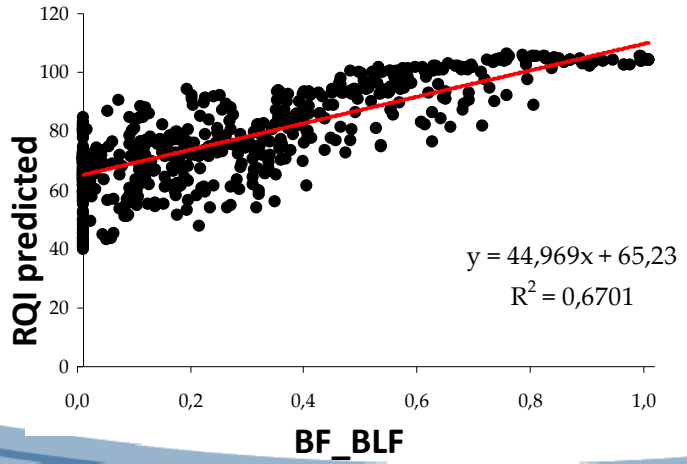
(C) @ an unconstrained-constrained-unconstrained valley transition

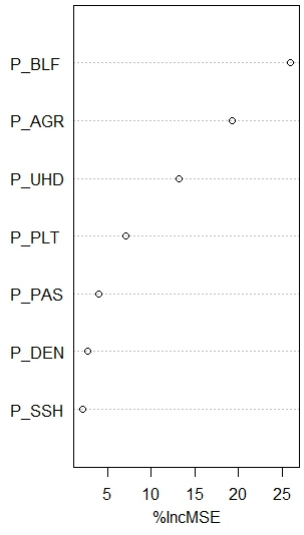


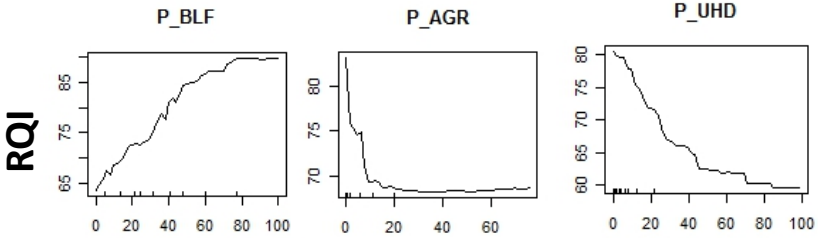
Results – RQI Large Scale Model

Riparian quality was strongly and positively related to Broadleaf forest extent, and negatively to the extent of agricultural and urban development in the riparian zone.



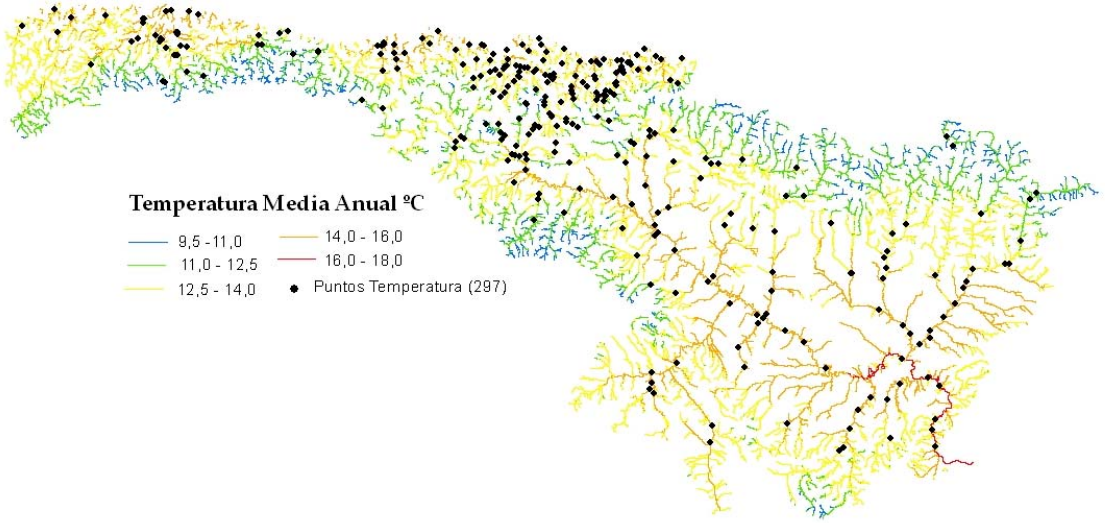


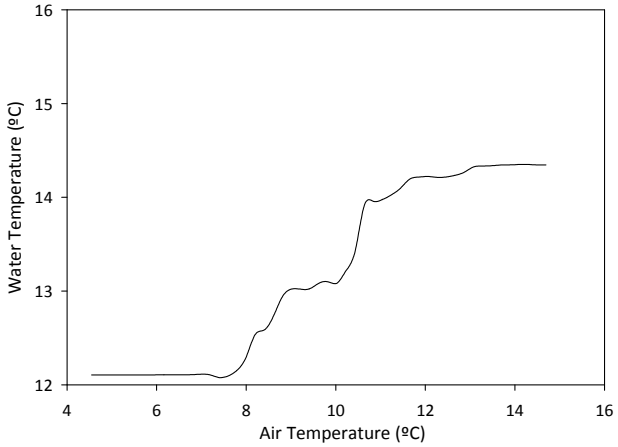


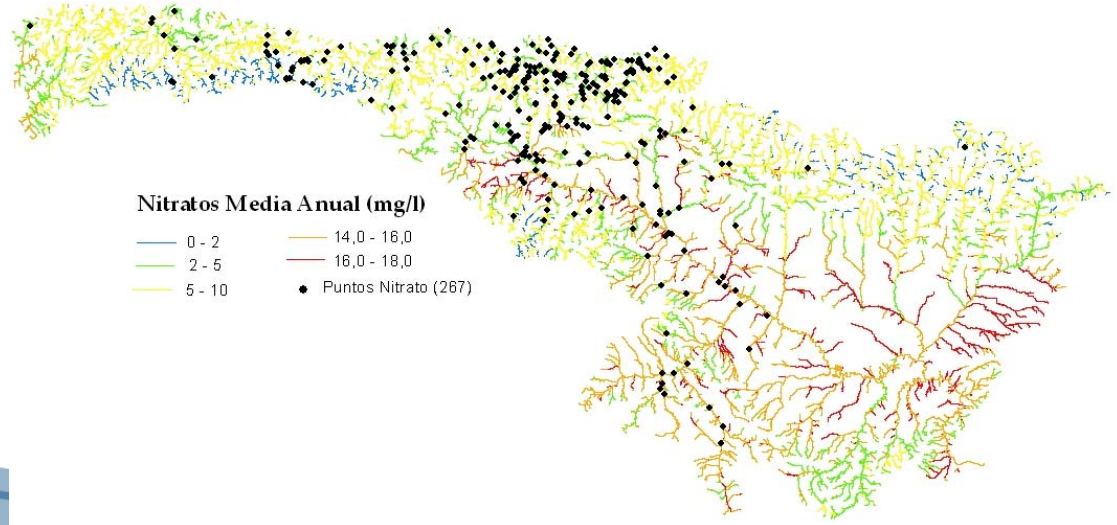


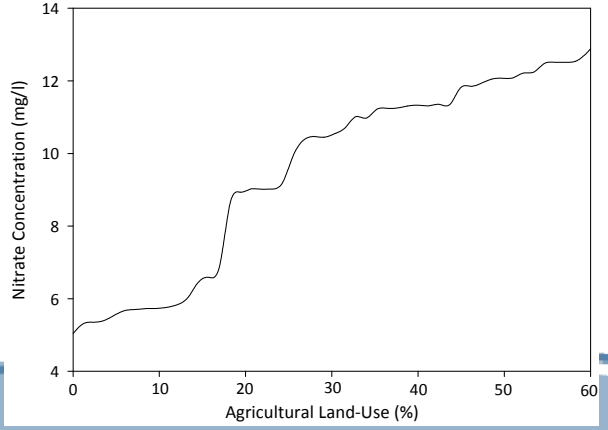
Results – Nitrate and Water Temperature

Water temperature was mainly controlled by air temperature, drainage area and forest cover, while nitrate concentration was highly influenced by agricultural development.





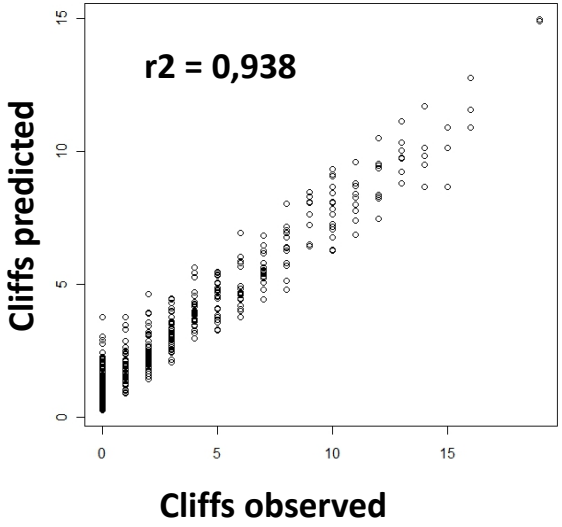


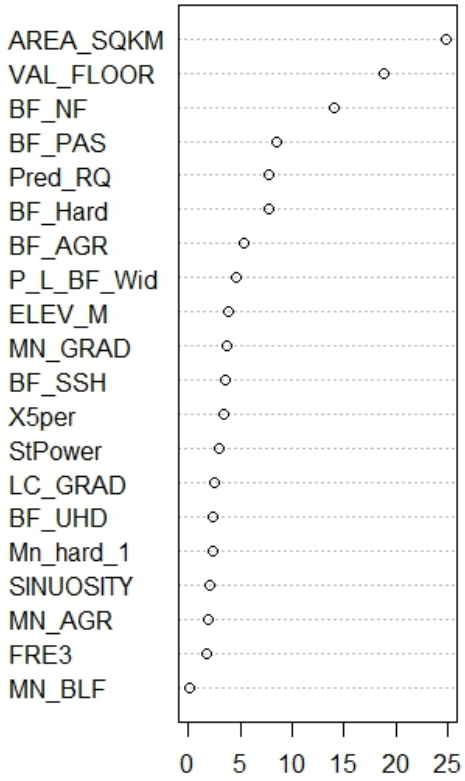


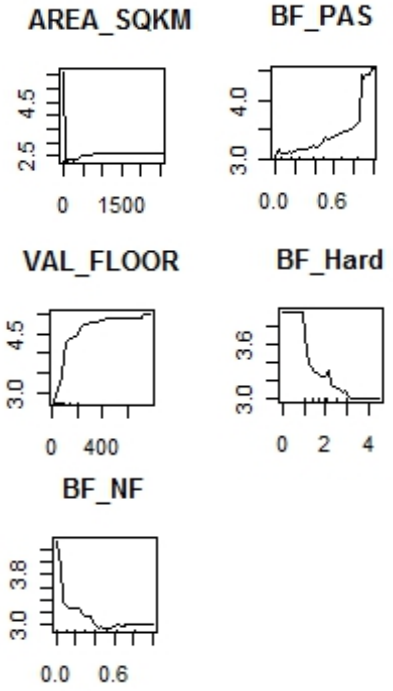
Results - Bank Erosion

Using Random Forest models to regress bank cliff abundance to catchment and riparian characteristics we obtained that catchment area, valley floor width, the amount of broadleaf forest and pasture within the riparian zone and substrate hardness were all important predictors.

Small catchments (< 100 km^2) with relative large valley floors (>150m) and earth bank materials are the ones in which riparian degradation might largely increase bank erosion.







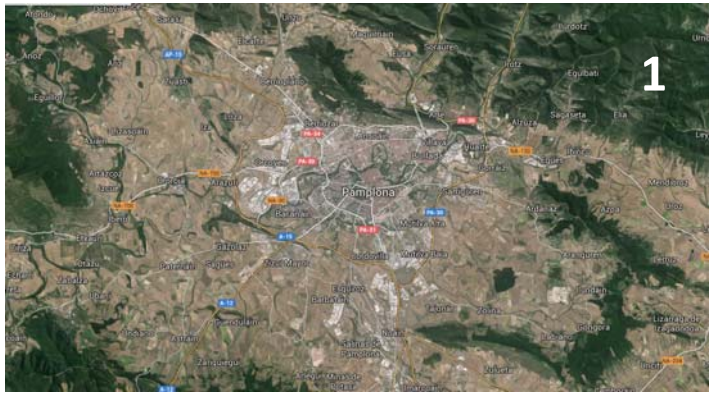
Results – Integration

We selected river reaches with bad conservation status (RQI<60: almost 4500 km a 14% of the total river network length). Out of those ones a 15% (690 km) have high annual water temperature (> 15ºC), nitrate concentration (>10 mg/l), bank cliff abundance, and potential for floodplain restoration (> 250 m).

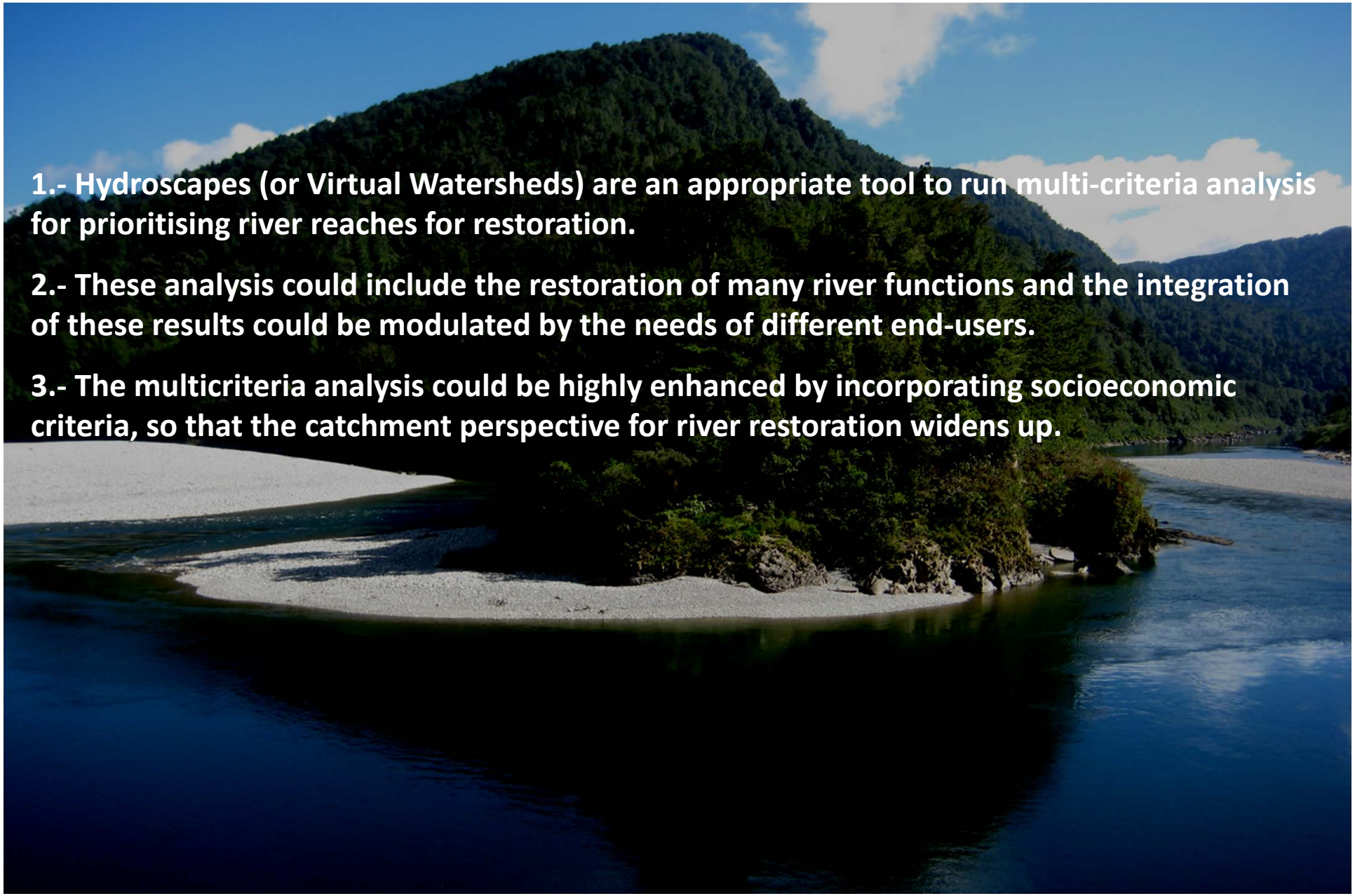
River Network

RQI < 60

RQI < 60 +
4 criteria



Conclusions



1.- Hydroscapes (or Virtual Watersheds) are an appropriate tool to run multi-criteria analysis for prioritising river reaches for restoration.

2.- These analysis could include the restoration of many river functions and the integration of these results could be modulated by the needs of different end-users.

3.- The multicriteria analysis could be highly enhanced by incorporating socioeconomic criteria, so that the catchment perspective for river restoration widens up.

Thanks a lot for your attention!

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