

D5.1 User guide for the web GIS application

Giorgio Pace[1], Stefano Larsen[2],

Massimiliano Scalici[3], Ralph Schulz[4], Monika Laux[4],

Micael Jonsson[5], José Barquín[6], Laura Concostrina-Zubiri[6]

[1] Centre of Molecular and Environmental Biology (CBMA), Uminho, Portugal

[2]Research and Innovation Centre, Fondazione Edmund Mach (FEM) Italy

[3]Uniroma3, Italy

[4]University Koblenz-Landau (UKL), Germany

[5]Umeå University (UMU), Sweden

[6]FUNDACIÓN INSTITUTO DE HIDRÁULICA AMBIENTAL DE CANTABRIA (FIHAC), Spain

1. BACKGROUND 3
2. METHODOLOGY 3
2.1. QUANTIFICATION OF RIPARIAN ECOSYSTEM SERVICES AND PRIORITY CLASSIFICATION 3
2.1.1. THERMAL LOADING REGULATION 4
2.1.2. DIFFUSE POLLUTION REGULATION 5
2.1.3. EROSION CONTROL 5
3. THE RIPARIANET WEB GIS APPLICATION 7
3.1. PURPOSE OF THE APPLICATION 7
3.2 GETTING STARTED 7
4. EXPLORING THE MAP 8
5. UNDERSTANDING CONSERVATION AND RESTORATION PRIORITIES 9
4. REFERENCES 10

1. BACKGROUND

Riparian zones are dynamic ecotones that play a fundamental role in aquatic ecosystems and contribute substantially to landscape biodiversity by providing habitat for numerous species and functioning as ecological corridors. Riparian areas with well conserved riparian forests perform essential functions, making them important providers of both provisioning and regulating ecosystem services (Riis et al., 2020). However, riparian forests have traditionally been subjected to anthropogenic disturbance, resulting in widespread alterations to their composition, structure, and functioning (Naiman et al., 2007).

Consequently, an essential component of riparian management at the catchment scale is the identification and prioritization of areas for conservation and restoration. This requires assessment frameworks capable of identifying riparian zones with high ecological value that merit protection, as well as degraded areas where restoration actions are most relevant to enhance ecosystem functioning and the provision of ecosystem services.

In RIPARIANET, we focused in regulation ecosystem services provided by riparian forests in relation to thermal loading, diffuse pollution and erosion. These services are particularly important for fluvial ecosystems because they help maintain water quality and suitable habitat conditions for aquatic organisms. Riparian forests moderates stream temperatures through shading, reducing thermal stress on sensitive species (Dugdale et al., 2018, Foote et al., 2025), while also filtering sediments, nutrients, and pollutants before they reach watercourses (Daniels & Gilliam, 1996). In addition, riparian forests stabilize riverbanks and floodplain soils (Biggs et al., 2025, Hubble et al., 2010), limiting erosion and sediment inputs that can alter channel morphology, degrade habitats, and impair ecological functioning.

2. METHODOLOGY

2.1. QUANTIFICATION OF RIPARIAN ECOSYSTEM SERVICES AND PRIORITY CLASSIFICATION

The quantification of riparian ecosystem services was carried out combining the use of virtual watersheds to identify relevant functional units of the fluvial landscape (e.g., river reaches and riparian zones), land cover data to calculate the cover of riparian forests, LiDAR data to obtain Digital Surface Models and environmental information (e.g., climate, topography).

We used the NetMap software (Benda et al. 2016) to create virtual watersheds for each RIPARIANET case study and delineate synthetic river networks from Digital Elevation Models (DEM) and historical precipitation data (see Jonsson et al., 2026, for details). The virtual watersheds were discretized into relevant landforms (Fig. 1), including hydrologically similar river reaches, reach drainage area and riparian zones (defined using a 2-bankfull depth approach, Fernandez *et al.*, 2012).

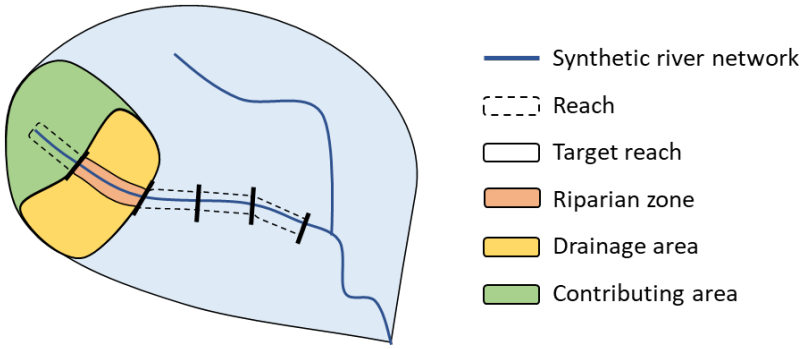


Figure 1. Functional units derived from the synthetic river networks (adapted from Benda et al., 2016).

Land cover data was calculated using the CORINE Land Cover 2018 map (CLC) from the Copernicus Land Monitoring Service, and LiDAR and environmental information was obtained from global and regional data bases (Jonsson et al., 2026).

To assign conservation and restoration priority values to riparian zones at the river-reach level, we classified reaches into four priority classes (very high, high, medium, and low) based on ecosystem service values, using basin-specific quartiles for each service (10th, 25th, and 50th quartiles).

The methodology for calculating ecosystem service values and assigning conservation and restoration priority classes is described below.

2.1.1. THERMAL LOADING REGULATION

Thermal loading regulation in river ecosystems describes the influence of riparian forest shade in reducing the amount of solar radiation reaching the channel. To quantify this effect, topographic information, riparian forest cover, and solar geometry were integrated within a GIS framework.

Solar radiation was estimated for each river network using the *Area Solar Radiation* tool in ArcGIS Pro. Calculations were performed using both a Digital Elevation Model (DEM) and a Digital Surface Model (DSM), the latter derived from LiDAR data and incorporating vegetation height and other above-ground features. By comparing radiation values from the DEM and DSM, the shading effect of riparian vegetation was quantified.

A thermal loading index (delta, Δ) was calculated as the difference between DEM- and DSM-derived radiation values. Positive delta values indicated areas receiving reduced radiation due to riparian shading, whereas values close to zero represented areas unaffected by vegetation cover. Pixel-level values were aggregated into the functional units “riparian zones”. Units with positive Δ values were proposed for conservation because they currently benefit from thermal regulation, whereas units with radiation exposure and $\Delta \approx 0$ were identified as restoration areas due to their potential to benefit from increased riparian shading.

Priority classes (very high, high, medium, and low) were assigned at the functional-unit level using a quartile-based approach. For conservation prioritization, only positive delta values were considered, as they indicate areas where the thermal loading function is currently provided. Delta values were aggregated within each functional unit, and the resulting sums were classified into quartiles to identify units with the highest contribution to this ecosystem service. For restoration prioritization, pixels with

near-zero delta values were selected, representing areas where the thermal loading function is currently absent. In these cases, radiation values were aggregated within functional units and classified into 10th, 25th, and 50th quartiles, with higher radiation levels indicating a greater potential benefit from restoration actions.

2.1.2. DIFFUSE POLLUTION REGULATION

Diffuse pollution originates from land-use activities such as agriculture, livestock and urban development and is largely transported through surface runoff. Riparian and hillslope forests can mitigate these impacts by reducing runoff and filtering sediments, nutrients, and other pollutants before they reach watercourses.

For this ecosystem service, we first estimated the potential runoff-derived inputs originating from hillslopes and reaching riparian zones. We then assessed the capacity of riparian forests to regulate these inputs through their filtering function.

Diffuse pollution regulation on hillslopes

The regulation of diffuse pollution was assessed through a Hydrological Response Index (HRI), representing the potential of hillslopes to generate runoff. The HRI integrated normalized slope and mean annual precipitation, two key drivers of runoff production. Values ranged from 0 to 1, with higher values indicating lower regulation capacity and greater runoff generation potential.

To account for the mitigating role of forests, pixels covered by natural forest were assigned positive values, reflecting the provision of runoff regulation service, whereas non-forested areas were assigned negative values. Values of the HRI were aggregated at the drainage area level.

Diffuse pollution regulation in riparian areas

The diffuse pollution regulation service provided by riparian forests was defined as the capacity of riparian forests to filter runoff-derived pollutants originating from adjacent hillslopes. Runoff delivery from non-forested hillslope areas was first estimated (aggregated HRI), representing potential pollutant inputs reaching the river network.

Riparian forest cover was then quantified within the riparian zone of each river reach using CLC information. Units with at least 60% riparian forest cover were considered effective providers of this ecosystem service and proposed for conservation, whereas units below this threshold were considered restoration areas. Priority classes were defined using the 10th, 25th, and 50th quartiles of aggregated HRI, separately for conservation and restoration riparian zones.

2.1.3. EROSION CONTROL

Erosion control was evaluated through two complementary processes: (i) erosion regulation at source on hillslopes and (ii) sediment filtering during transport within riparian zones. Together, these processes capture the role of forests in reducing sediment generation and limiting sediment delivery to river networks.

Erosion regulation on hillslopes

Potential erosion was estimated using a Generic Erosion Potential (GEP) index derived from a 5-m Digital Terrain Model. The index incorporated local contributing area, slope, and topographic convergence, with higher values indicating greater erosion susceptibility.

Sediment delivery pathways from each pixel to the nearest watercourse were delineated using NetMap. The probability of sediment reaching the channel was combined with GEP values to estimate the potential contribution of each pixel to sediment delivery. Forest cover was incorporated by assuming reduced erosion and sediment export from forested areas. Sediment delivery values were aggregated at the drainage area level.

Erosion regulation in riparian areas

Riparian erosion regulation was defined as the capacity of riparian forests to intercept and filter sediments transported from adjacent hillslopes. Sediment delivery from non-forested hillslope areas was first estimated to identify reaches exposed to high sediment loads.

Riparian forest cover was then quantified for each riparian zone using CLC information. Riparian zone units with ≥60% forest cover were considered effective sediment filters and proposed for conservation, whereas units with lower forest cover were classified as restoration areas. Priority classes were defined using the 10th, 25th, and 50th quartiles of sediment potentially delivered to the river network (aggregated sediment delivery values), separately for conservation and restoration units.

3. THE RIPARIANET WEB GIS APPLICATION

3.1. PURPOSE OF THE APPLICATION

The RIPARIANET Web GIS application, available at https://riparia-mapa.propostas2.netgocio.pt/pt/; and at https://riparianet.eu/), was designed as a spatial decision-support tool for exploring riparian areas and identifying river reaches that may be priorities for conservation or restoration.

The Web GIS application displays the results of riparian forest ecosystem services obtained for the five RIPARIANET case study areas, namely:

Thermal loading regulation: the role of riparian vegetation in shading rivers and reducing solar radiation reaching the channel.

Diffuse pollution regulation: the capacity of riparian forests to filter runoff and reduce the delivery of sediments, nutrients and other pollutants.

Erosion control: the contribution of forests to reducing soil erosion and intercepting sediment before it reaches rivers.

The application supports the identification of areas with high conservation value and areas where restoration could improve riparian ecosystem functioning, as described in the previous section.

3.2 GETTING STARTED

Open the RIPARIANET Web GIS application (Fig. 2).

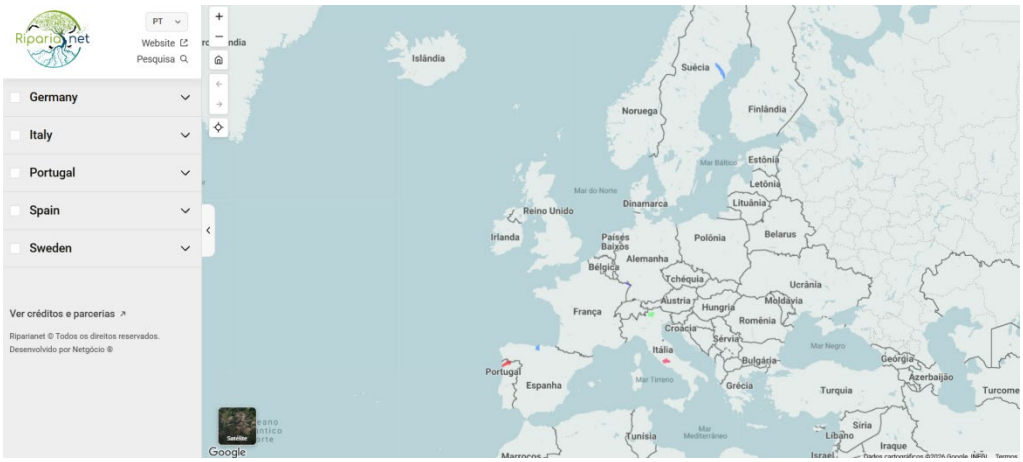
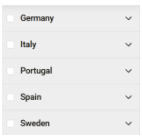


Figure 2: Web Application Home page



Select your preferred language using the language options at the top of the page and consult our Web GIS application.

Selecting a study area



The navigation panel organizes the study areas by country and river basin. Available case study areas include:

Germany: Lauter and Queich.

Italy: Aniene and Noce.

Portugal: Cávado.

Spain: Saja.

Sweden: Sävarån.

Expand or select the relevant country and river basin (e.g., Fig 3) to explore the available spatial information.

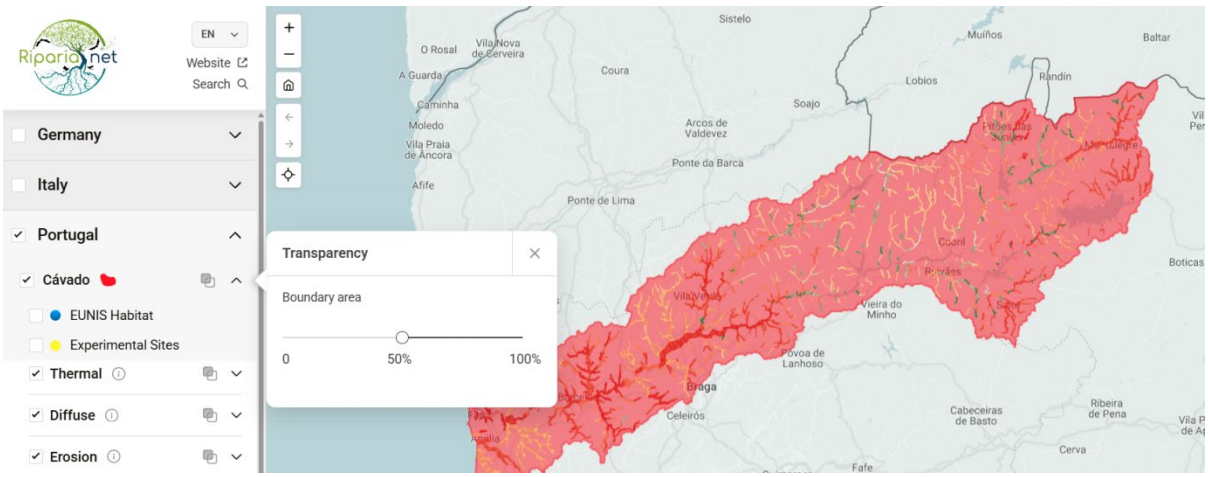


Figure 3: the Cavado river basin, a selected case study area of Riparianet

4. EXPLORING THE MAP

Use the map to navigate through the selected study area and inspect the spatial information displayed.

Map navigation: move around the map to explore different locations and river reaches.

Satellite view: select the satellite basemap option to view the landscape using satellite imagery.

Transparency: adjust the transparency slider to change the visibility of the displayed map information relative to the underlying map.

Layer exploration: use the available map and information controls to explore the datasets presented by the application.

The exact behaviour of individual map controls may depend on the selected layer and the current application view.

5. UNDERSTANDING CONSERVATION AND RESTORATION PRIORITIES

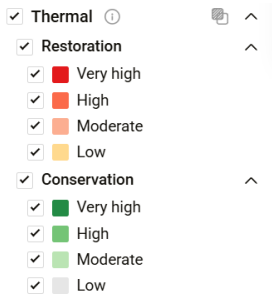
The RIPARIANET methodology classifies river reaches into four priority levels:

Very high

High

Medium

Low



These classes are based on ecosystem-service indicators and basin-specific statistical thresholds (e.g., Fig. 3, see section 2 for details).

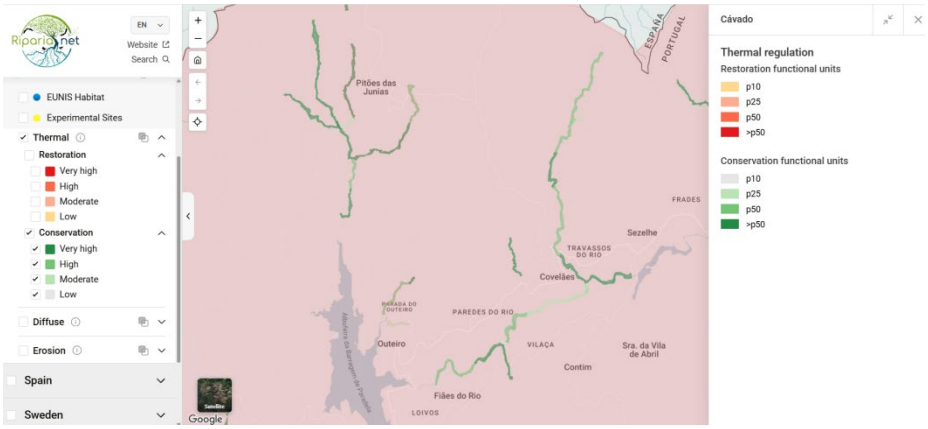


Figure 3: The Cavado river basin, a selected case study area of RIPARIANET

Conservation priorities identify areas where riparian vegetation is already contributing to ecosystem services and where protection contribute to maintain these services.

Restoration priorities identify areas where ecosystem-service provision is absent or limited and where restoration offers potential benefits.

The interpretation depends on the ecosystem service being assessed:

Ecosystem service	
Thermal loading regulation	Existing riparian shade and potential benefits from increased shading
Diffuse pollution regulation	Riparian forest capacity to filter runoff-derived pollutants
Erosion control	Riparian forest capacity to intercept sediments and reduce erosion impacts

For diffuse pollution regulation and erosion control, riparian forest cover of at least 60% is used in the underlying methodology as a criterion for identifying effective service provision. Thermal regulation uses a different approach based on solar radiation and vegetation shading (see section 2 for details).

In situ Riparian EUNIS Habitats and RIPARIANET - field experimental sites are also visible through the application (Figure 4)

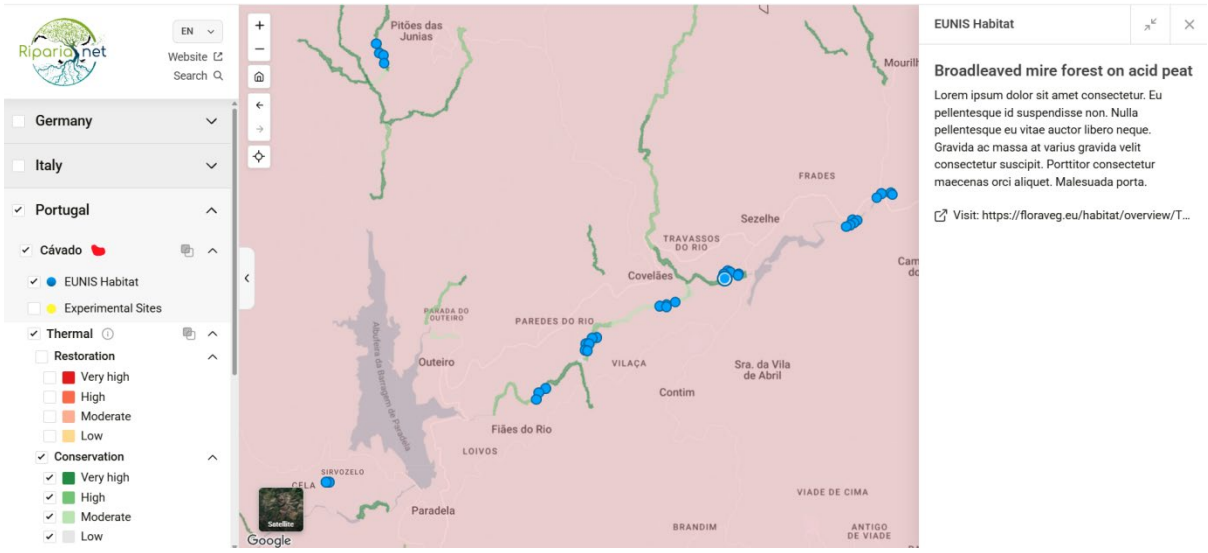


Figure 4: Riparian Eunis Habitat validated during the RIPARIANET Project

4. REFERENCES

Benda, L., Miller, D., Barquin, J., McCleary, R., Cai, T., & Ji, Y. (2016). Building virtual watersheds: a global opportunity to strengthen resource management and conservation. *Environmental Management*, *57*(3), 722-739.

Biggs, H., Haddadchi, A., Brasington, J., Bind, J., & Stout, J. (2025). The impact of riparian vegetation on bank erosion during extreme weather events. *Earth Surface Processes and Landforms*, *50*(10), e70136.

Daniels, R. B., & Gilliam, J. W. (1996). Sediment and chemical load reduction by grass and riparian filters. *Soil Science Society of America Journal*, *60*(1), 246-251.

Dugdale, S. J., Malcolm, I. A., Kantola, K., & Hannah, D. M. (2018). Stream temperature under contrasting riparian forest cover: Understanding thermal dynamics and heat exchange processes. Science of the Total Environment, 610, 1375-1389.

Fernández, D., Barquín, J., Álvarez-Cabria, M., & Peñas, F. J. (2012). Quantifying the performance of automated GIS-based geomorphological approaches for riparian zone delineation using digital elevation models. *Hydrology and Earth System Sciences*, *16*(10), 3851-3862.

Foote, A. W., Sanders, A. M., Coble, A. A., & Warren, D. R. (2025). Stream Temperature Response to Riparian Buffer Configurations: A Replicated Experiment Across Oregon's Coast Range. Hydrological Processes, 39(10), e70278.

Hubble, T. C. T., Docker, B. B., & Rutherfurd, I. D. (2010). The role of riparian trees in maintaining riverbank stability: a review of Australian experience and practice. *Ecological Engineering*, *36*(3), 292-304.

Jonsson, M., Concostrina-Zubiri, L., Bruno, M. C., Cássio, F., Cesarini, G., Gallitelli, L., ... & Barquín, J. (2026). Wood decomposition in European rivers increases with temperature but decreases with human population density. *Ecology and Evolution*, *16*(6), e73821.

Riis, T., Kelly-Quinn, M., Aguiar, F. C., Manolaki, P., Bruno, D., Bejarano, M. D., ... & Dufour, S. (2020). Global overview of ecosystem services provided by riparian vegetation. *BioScience*, *70*(6), 501-514.

Naiman, R. J., Decamps, H., McClain, M. E., & Likens, G. E. (2007). *Riparia: ecology, conservation, and management of streamside communities*. Academic Press.