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RESEARCH ARTICLE

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Habitat, plant landscape and biodiversity of Ofanto River (southern Italy)

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Abstract

The Ofanto River represents one of the main fluvial systems of southern Italy in terms of extent, ecological value, and landscape role. This study reconstructed the plant vegetation landscape along the riverbanks, from the source to the mouth of the river, through the development of a thematic cartography and the classification of habitats according to CORINE Biotopes codes. The approach integrated spatial analysis with field surveys, photointerpretation to validate *in situ* observations, and comparison with existing cartography. The analysis identified a total surface area of 26.97 km², with a clear predominance of riparian forests of *Populus* sp. pl. and *Salix* sp. pl. poplars and willows, covering 64.88% of the area. These are followed by Mediterranean downy oak woodlands (25.06%), temperate shrub lands with deciduous broadleaves (3.70%), conifer reafforestation (4.78%), and reed beds dominated by *Phragmites australis* (1.58%). The results highlight a gradient of increasing naturalness upstream, with riparian formations representing the structural backbone of the riverine ecological network. The study emphasizes the need for integrated management of the Ofanto corridors, focusing on the conservation of natural habitats, the control of invasive species, and the preservation of ecological connectivity across the landscape.

Keywords

Alien species, conservation, plant diversity, riparian forests, spatial analysis

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Introduction

Rivers are dynamic and complex ecosystems whose significance extends far beyond the mere presence of water. They play a crucial role in maintaining biodiversity, regulating hydrological cycles, transporting sediments and nutrients, and supporting surrounding socio-ecological systems (Dudgeon et al. 2006; Cummins and Wilzbach 2019). Riverbanks, wetlands, and channels host a wide range of habitats, from riparian forests to gravel bars, from stagnant water bodies to floodplain areas, providing shelter, food resources, and migration corridors for numerous animal and plant species (Tockner and Stanford 2002; Halabowski et al. 2020; Musisi et al. 2025).

Beyond their ecological functions, rivers provide essential ecosystem services to human communities, including the supply of freshwater for domestic, agricultural, and industrial uses, the recharge of groundwater, the regulation of flow and flood events, the fertilization of alluvial plains, and opportunities for recreational, cultural, and economic activities (Postel and Richter 2003). However, in recent decades, river systems have been increasingly subjected to anthropogenic pressures that threaten their ecological integrity and their capacity to deliver critical ecosystem services (Zhu et al. 2023). Intensive agriculture, through the extensive use of fertilizers and pesticides, alters water quality and soil characteristics along the banks, while water abstraction for urban, industrial, or irrigation purposes modifies natural flow regimes, undermining hydrological balance and the ecological functioning of rivers (Ekka 2020; Castro et al. 2025). Channel modifications such as straightening, embankment construction, dredging, and disconnection from floodplains reduce morphological complexity, degrade habitats, and compromise the longitudinal and lateral connectivity required by many species for migration, reproduction, and movement (Lewin et al. 2024). These alterations, when combined with pollution and intensive land use, reduce the resilience of riverine landscapes, limiting the capacity of ecosystems to recover from chronic stress or extreme events (Bunn and Arthington 2002; Palmer et al. 2005).

Within this context, understanding and characterizing river habitats, vegetation distribution, and floristic-ecological diversity is essential for the sustainable management and conservation of freshwater systems (Ward et al. 2002; Veról et al. 2020). Only through an integrated analysis of channel structure, bank morphology, hydrological gradients, and plant communities is it possible to assess anthropogenic impacts, identify the most vulnerable areas, and develop effective strategies for conservation and ecological restoration.

The Ofanto River crosses Campania, Basilicata and Apulia, flowing from its mountainous upper sector down to the alluvial plain (Verri et al. 2017). Its landscape is shaped by intensive agriculture (Campanale et al. 2020) and highly variable discharges (Campanale et al. 2024). The river corridor, mainly gravelly, hosts valuable habitats (Campanale et al. 2020), partly included within the “Fiume Ofanto” Regional Natural Park (Regione Puglia 2007, 2009) and the SIC/ZSC “Valle

dell'Ofanto – Valle di Capacciotti" (Ministero dell'Ambiente e della Tutela del Territorio e del Mare 2018). Despite pressures from agriculture, geomorphological alterations (De Santis et al. 2018) and microplastic pollution (Campanale et al. 2020), it still preserves stretches of high ecological value.

In this framework, habitat mapping was carried out along the riverbanks, and the aim of this study is to reconstruct the forested plant landscape along the Ofanto River from its source to its mouth.

Materials and methods

Study area

The Ofanto River, approximately 170 km long with a catchment area of over 2,700 km², is one of the most important fluvial systems in southern Italy for its ecological and landscape value. It originates on the Irpinia highland, in Campania, south of Torella dei Lombardi (40°55'59"N, 15°07'01"E), at an altitude of about 715 m a.s.l. (QGIS Development Team 2023), and flows through Campania, Basilicata, and Apulia, crossing 23 municipalities before entering the Adriatic Sea south of Lake Salpi (Verri et al. 2017), near the town of Barletta (41°21'30"N, 16°11'50"E) (Fig. 1).

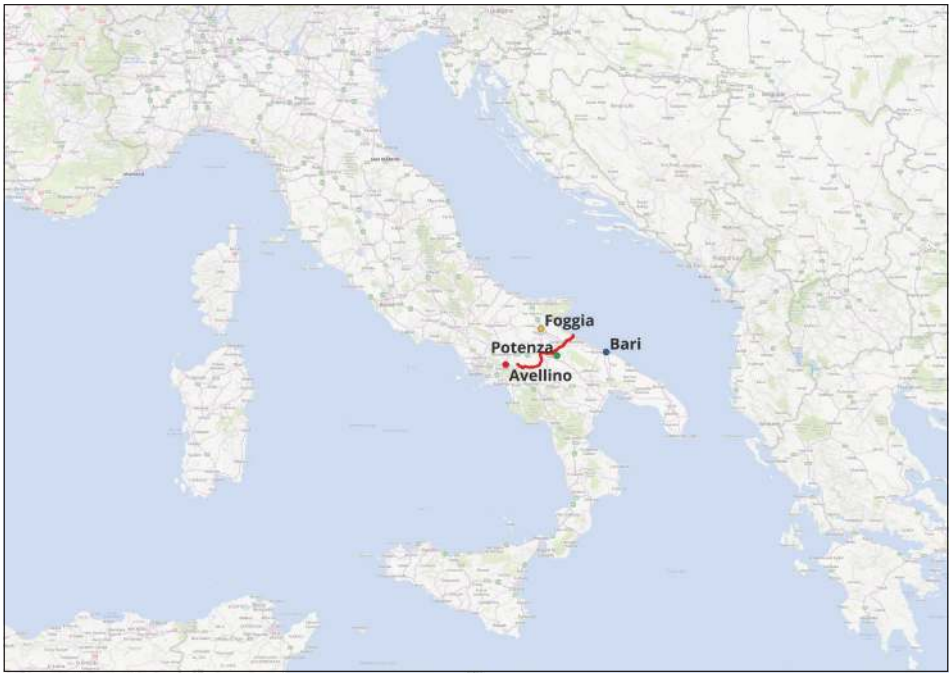


Figure 1. Geographical location of the Ofanto riverbed (Southern Italy).

The basin can be divided into two main sectors: the upper, mountainous and hilly reach, and the lower, alluvial plain (Verri et al. 2017). The landscape is dominated by intensive agriculture, with both arboreal and irrigated crops, differentiated between the Tavoliere plain (cereal crops) and the Alta Murgia area (vineyards, olive groves, and agro-silvo-pastoral mosaics) (Campanale et al. 2020). Mean annual precipitation is approximately 720 mm, with average temperatures of 14 °C (Romano et al. 2009), while the river exhibits a torrential hydrological regime, with discharges ranging from about 1 m^3/s in summer to 35–40 m^3/s in winter, and an average flow at the mouth of around 15 m^3/s (Campanale et al. 2024).

The river corridor is composed mainly of gravelly alluvial deposits and serves as an important ecological habitat (Campanale et al. 2020). The natural and cultural heritage of the river is protected by the Regional Natural Park "Fiume Ofanto", established by Regional Law No. 37/2007 and amended by Law No. 7/2009 (Regione Puglia 2007, 2009). The park, divided into the Lower Valley, Middle Valley, and Locone Stream Valley, partially overlaps with the Site of Community Importance (SCI) "Valle dell'Ofanto – Valle di Capacciotti" (IT9120011), designated as a Special Area of Conservation (SAC) by Ministerial Decree of 21 March 2018 (Ministero dell'Ambiente e della Tutela del Territorio e del Mare 2018), covering a total area of approximately 25,000 hectares.

From a floristic point of view, the area shows remarkable environmental heterogeneity, including wetlands, woodlands, shrub vegetation, and cultivated areas. The river acts as a key ecological corridor for many Mediterranean species. Among the most notable stretches, Ripalta (Cerignola, Foggia) stands out for its sandstone cliff, sculpted by fluvial erosion, and its well-preserved riparian vegetation.

However, in recent centuries, the Ofanto River has undergone geomorphological transformations due to both natural processes and human activities, such as intensive agriculture, water abstraction, and channel modification (De Santis et al. 2018). Moreover, the river shows a significant presence of microplastics, likely derived from agricultural practices (Campanale et al. 2020). Despite these anthropogenic pressures, the river still preserves stretches of high ecological value, which require targeted conservation and management strategies. To this end, a detailed habitat cartography was carried out along the riverbanks to identify and classify the different habitat types occurring along the river course, providing a reference framework for future monitoring of changes due to anthropogenic pressures or natural processes.

Spatial analysis

The cartography and classification of habitats along the Ofanto River were carried out using a spatial analysis approach that combines field surveys, photointerpretation to validate on-site observations, and comparison with existing cartography, in order to obtain a comprehensive and coherent knowledge framework.

Surveys were conducted in August and September 2025 through a census and analysis of the characteristic species present along the riverbanks.

A thematic map at a scale of 1:100.000 was created for the different stretches of the Ofanto River. The river was divided into four main sections, each represented separately to highlight the specific environmental and territorial characteristics of each stretch. The maps were produced using QGIS software (QGIS Development Team 2023), applying a minimum mapping unit set at 25 linear meters and 625 m² (Domina et al. 2025). Features smaller than this threshold were merged with adjacent polygons. For each created shapefile, an attribute table was compiled including the main geometric characteristics, such as polygon area, along with all relevant information regarding land use.

The cartographic data related to the Ofanto River were analyzed and classified using CORINE Biotopes codes (Commission of the European Communities 1991), a European reference system for the typology and cataloguing of natural and semi-natural habitats. Taxonomic nomenclature for observed species was referenced from Bartolucci et al. (2024) and Galasso et al. (2024).

This methodology allows each territorial unit to be associated with a coded ecological category, ensuring consistency in the description of natural environments at the European level (Moss and Wyatt 1994). Finally, for each digitized habitat type, both the absolute area (in km²) and the percentage relative to the total hydrographic network of the Ofanto River were calculated (Table 1).

Results

Along the course of the Ofanto River (Fig. 1), a marked differentiation in vegetation cover was observed according to the different stretches considered.

Starting from the river mouth (Fig. 2), the habitat is dominated by reed beds of *Phragmites australis* (Cav.) Trin. ex Steud. (code 53.1 – *Phragmites australis* and other helophyte reed beds) (Fig. 3), accompanied by communities of *Tamarix canariensis* Willd. and *T. arborea* (Sieber ex Ehrenb.) Bunge (Fig. 4), as well as riparian species such as *Glycyrrhiza glabra* L. and halophytes such as *Limonium narbonense* Mill. and *Limbarda crithmoides* (L.) Dumort. subsp. *longifolia* (Arcang.) Greuter (Fig. 5).

Table 1. Analysis of surface area in km² and % of habitats relating to the course of the River Ofanto (Southern Italy). Habitats are listed according to CORINE Biotopes codes.

Habitat	Km²	%
31.81 Temperate deciduous broadleaf scrublands	1.00	3.70
41.732 Mediterranean oak forests with downy oak	6.76	25.06
44.61 Riparian forests of poplar and willow trees	17.50	64.88
53.1 Reed beds with *Phragmites australis* and other helophytes	0.42	1.58
83.31 Conifer plantations	1.29	4.78
Total	**26.97**	

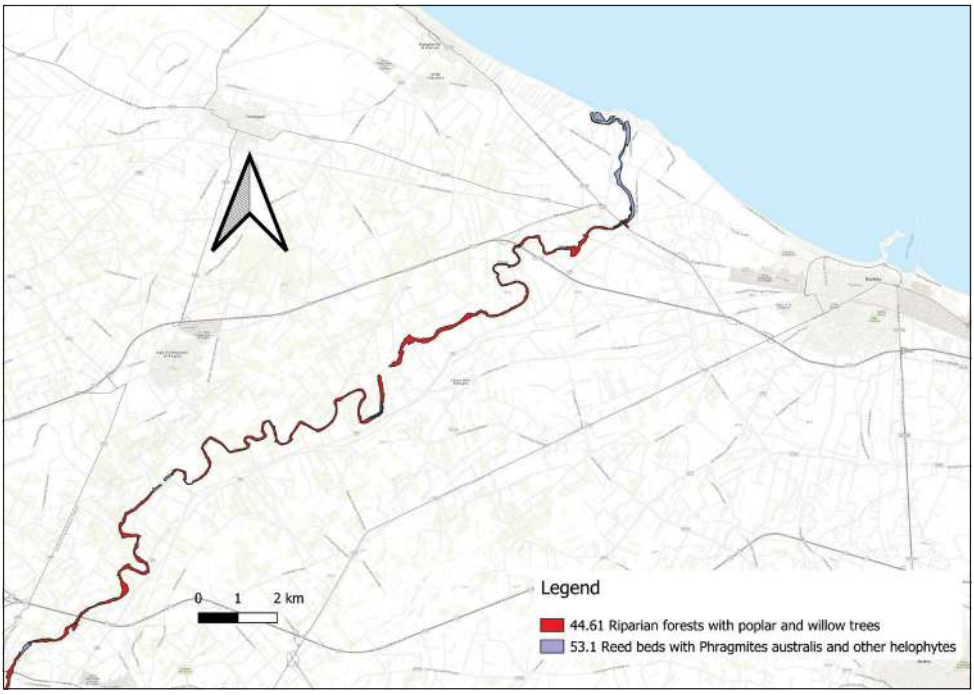


Figure 2. Main types of riparian habitats found along the course of the Ofanto River, from its mouth to the territory of Canosa (Foggia, Southern Italy).



Figure 3. Vegetation with *Phragmites australis* (Cav.) Trin. ex Steud. at the mouth of the Ofanto River (Southern Italy).



Figure 4. *Tamarix arborea* (Ehrenb.) Bunge (**a**) and *Glycyrrhiza glabra* L. (**b**) at the mouth of the Ofanto River (Southern Italy).



Figure 5. Vegetation with *Limonium narbonense* Mill. and *Limbarda crithmoides* (L.) Dumort. subsp. *longifolia* (Arcang.) Greuter near the mouth of the Ofanto River (Southern Italy).

Moving inland, these communities gradually give way to riparian vegetation, predominantly composed of riparian forests of poplars and willows (code 44.61).

Near Canosa di Puglia (Fig. 6), the vegetation landscape is characterized by riparian forests of *Populus nigra* L. and *Salix alba* L. (Fig. 7), with residual patches of *P. australis* reed beds. In this stretch, other trees and shrubby species also appear, such as *Ficus carica* L., *Olea europaea* L., *Crataegus monogyna* Jacq., and *Capparis spinosa* L.

Along the stretch of the Ofanto River between the hamlets of Loconia (Puglia) and San Nicola di Melfi (Basilicata) (Fig. 8), riparian forests of *P. nigra* and *S. alba* continue to dominate, although in a more fragmented form compared to previous stretches. A peculiarity of this area is the presence of *Populus alba* L. and the invasive *Robinia pseudoacacia* L. (Fig. 9), which substantially alters the original composition of the riparian vegetation. In this stretch, *Xanthium strumarium* L., a nitrophilous and ruderal synanthropic riparian herbaceous species, is abundant (Fig. 10).

Further upstream, the course of the Ofanto river shows a progressive increase in floristic richness, with the establishment of more mesophilous vegetation communities attributable to *Quercus pubescens* Willd. forests (code 41.732 – Mediterranean downy oak forests) (Fig. 11). In this stretch, stands of *Q. pubescens* and *Fraxinus ornus* L. are observed (Valle Refezzella, Potenza) (Fig. 12), accompanied by shrubs such as *C. monogyna*, *Prunus spinosa* L., and *Rosa canina* L., contributing to the formation of the temperate deciduous broadleaf scrub habitat

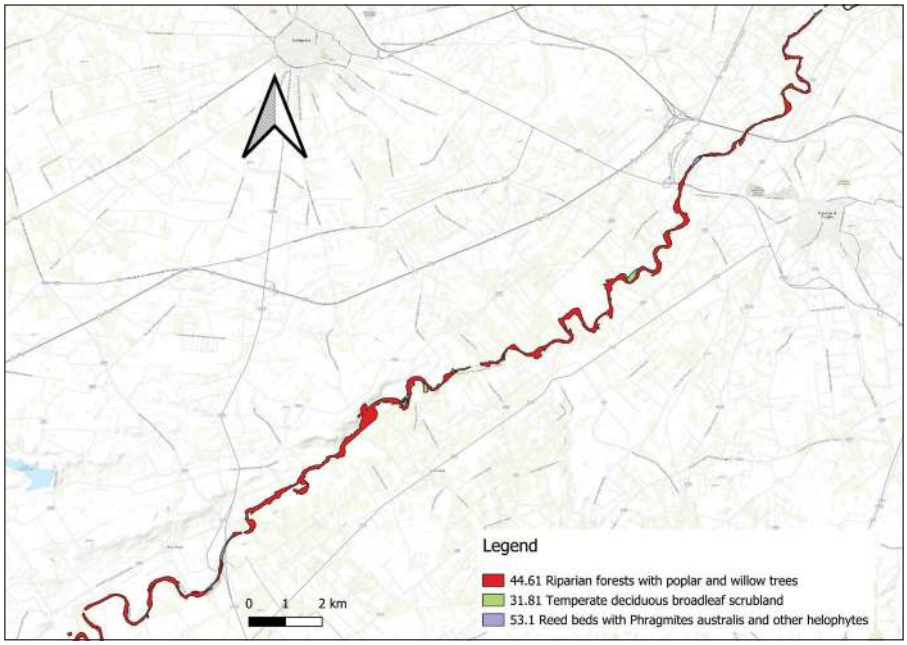


Figure 6. Main types of habitats found along the course of the Ofanto river in the territory of Canosa di Puglia (Foggia, Southern Italy).



Figure 7. Riparian vegetation with *Populus nigra* L. and *Salix alba* L. near the Roman Bridge close to the town of Canosa di Puglia (Foggia, Southern Italy).

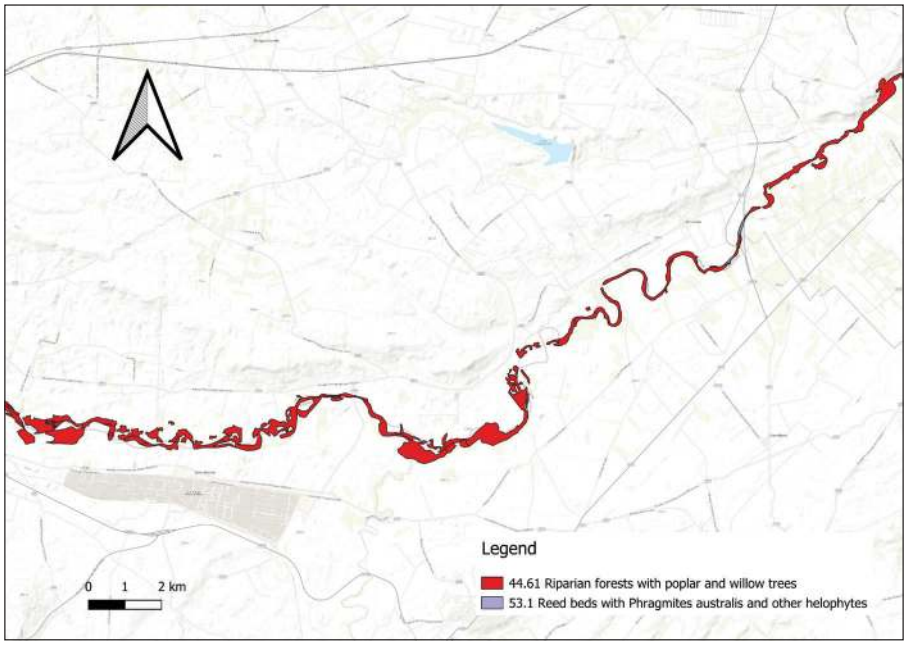


Figure 8. Main types of riparian habitats along the course of the Ofanto River in Southern Italy, from the hamlet of Loconia (Apulia) to the territory of San Nicola di Melfi (Basilicata).



Figure 9. Widespread presence of the invasive *Robinia pseudoacacia* L. along the course of the Ofanto River, near Leonessa di Melfi (Potenza, Southern Italy).

(code 31.81). In this portion of the basin, conifer reafforestations are also present (code 83.31 – conifer plantations), mainly *Pinus halepensis* Mill. woods, particularly near Monteverde.

Finally, approaching the source areas, the vegetation is characterized by typical riparian forests of mountain stretches, dominated by *S. alba* (Fig. 13), with a consistent presence of *P. nigra* and *Ulmus minor* Mill.

The cartographic analysis of the habitats along the banks of the Ofanto River, conducted through the CORINE Biotopes classification, identified a total surface area of 26.97 km² (Table 1). The distribution of forest types shows a clear predominance of riparian poplar and willow woodlands (code 44.61), which cover about 17.50 km², corresponding to 64.88% of the studied area. This figure highlights the central role of riparian formations within the ecological structure of the river corridor, confirming their key function in ecosystem processes and biodiversity conservation.

The Mediterranean oak forests with downy oak (code 41.732) represent the second most extensive category, with 6.76 km² (25.06%), significantly contributing to landscape diversification and to the ecological connection with the surrounding hilly areas.

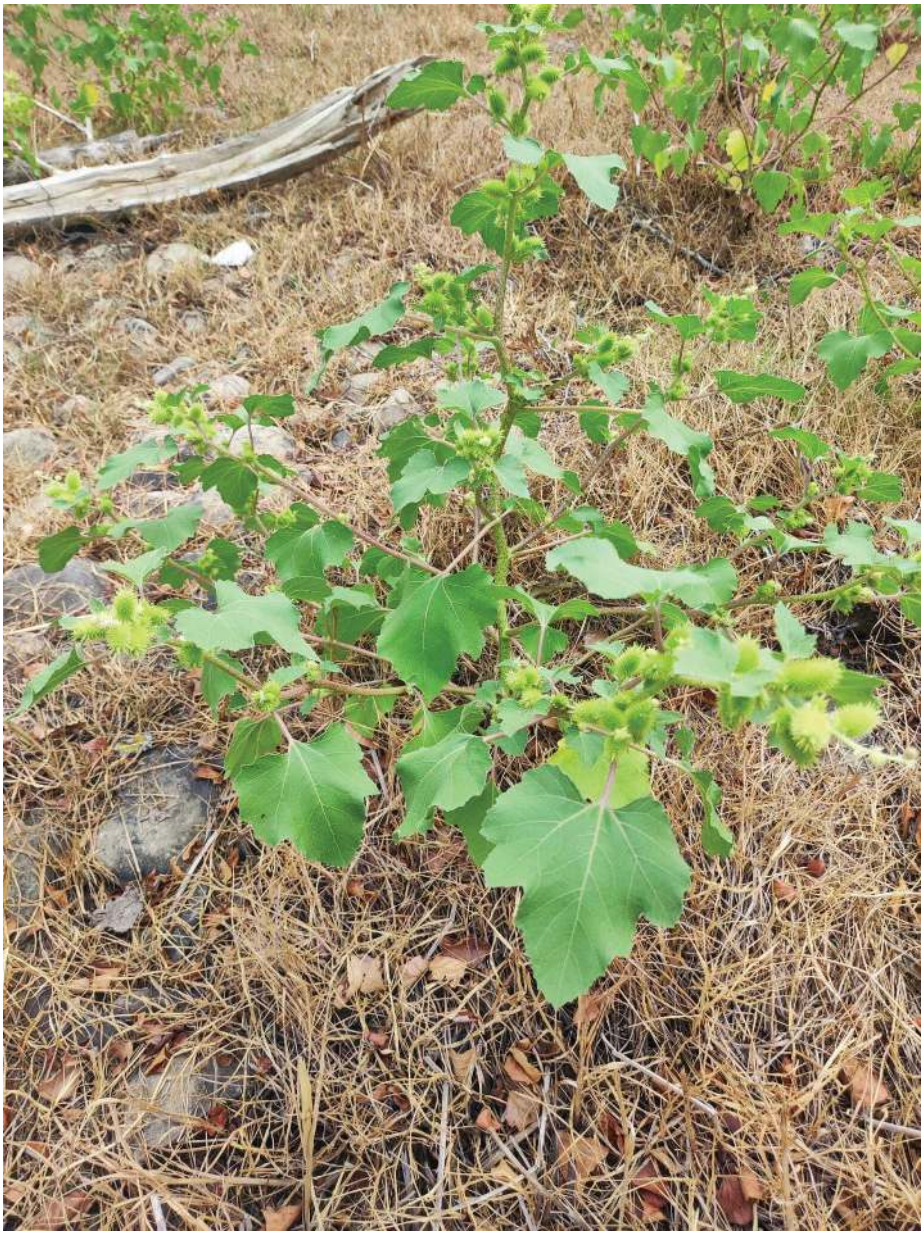


Figure 10. *Xanthium strumarium* L., a common riparian and synanthropic herbaceous species along the stretch of the Ofanto River near Leonessa di Melfi (Potenza, Southern Italy).

Temperate deciduous broadleaf shrublands (code 31.81) are less widespread, with a coverage of 1.00 km² (3.70%), while conifer plantations (code 83.31) extend over 1.29 km² (4.78%), reflecting artificial reforestation efforts.

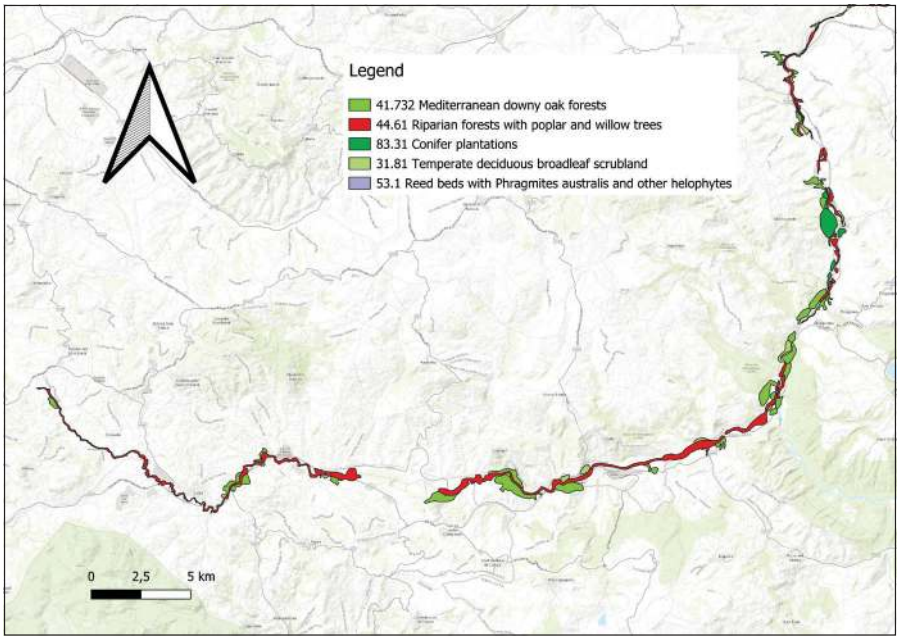


Figure 11. Main types of habitats found along the course of the Ofanto River (Southern Italy), from the hamlet of San Nicola di Melfi (Basilicata) to its source in the municipality of Torella dei Lombardi (Campania).



Figure 12. Mesophilous riparian forest along the stretch of the Ofanto River near Valle Refezzella (Potenza, Southern Italy).

Finally, the hygrophilous habitats of reed beds with *Phragmites australis* and other helophytes (code 53.1), although covering a limited area (0.42 km², equal to 1.58%), play an important role as wetland refuges and breeding sites for various faunal species linked to fluvial ecosystems.



Figure 13. Riparian vegetation dominated by *Salix alba* L. near Calitri (Avellino, Campania, Southern Italy).

Discussion

The vegetation analysis along the Ofanto River highlights a marked ecological and floristic differentiation, closely dependent on environmental gradients extending from the coastal zone to the headwater areas. The results show that this pattern reflects the typical dynamics of Mediterranean fluvial systems, where hydrological variability, sediment characteristics, water availability, and anthropogenic pressures interact to shape the structure and composition of plant communities (Naiman et al. 2010; Gurnell et al. 2016). Moving from the lower course upstream, a clear increase in naturalness emerges, accompanied by a progressive rise in floristic and functional complexity. In the coastal sector, *Phragmites australis* reed beds and halophilous communities dominate, whereas in the inland stretches these formations give way to extensive riparian forests dominated by *Populus nigra* and *Salix alba*, which constitute the ecological backbone of the entire river corridor. These forests, covering approximately two-thirds of the surveyed area, play a fundamental role in bank geomorphological stabilization, hydrological regulation, and natural water purification processes, as well as serving as essential elements for ecological connectivity and species dispersal along the river axis (Bita-Nicolae et al. 2024; Markus-Michalczyk et al. 2024). Their importance is also recognized at the European level, as several types of riparian forests are listed as habitats of community interest in Annex I of the Habitats Directive 92/43/EEC (European Council 1992) and constitute key elements of the Natura 2000 network (European Commission 2013). However, the results also indicate that these formations are significantly fragmented in the middle and lower reaches due to agricultural expansion, infrastructure development, and urbanization, reducing the continuity and functionality of ecological corridors, contrary to the requirements of Article 10 of the

Habitats Directive 92/43/EEC (European Council 1992), which emphasizes the need to maintain and restore connectivity between natural habitats.

In addition to riparian forests, the results highlight the significant presence of *Quercus pubescens* forests in the hilly areas of the basin, representing the second most extensive habitat category and serving as transitional ecosystems between fluvial and hilly environments, contributing to landscape diversification and the maintenance of ecological linkages between lowland and mountain areas. These formations, characterized by a rich floristic component and species associated with less disturbed conditions, are also included among habitats of community interest protected under the Habitats Directive 92/43/EEC (European Council 1992) and constitute indicators of high ecological integrity (Potenza et al. 2022). Deciduous broadleaf scrublands, although less widespread, represent additional elements of ecological diversity and dynamism; they often arise from local disturbances such as fires, cutting, or flooding and may evolve into mature forest communities in the absence of further pressures (Bourgeois et al. 2016). Their presence contributes to the resilience of the riverine system by promoting soil recolonization and increasing environmental heterogeneity in ecologically simplified contexts, in line with the objectives of the European Biodiversity Strategy 2030 (European Commission 2020), which promotes the restoration of degraded ecosystems.

The results also indicate the spread of artificial conifer plantations, mainly established for hydrogeological protection. While these plantations have stabilized some slopes, they have inevitably caused structural and floristic simplification compared to the original forests (Falcucci et al. 2007). The issue is further exacerbated by the presence of invasive alien species, particularly *Robinia pseudoacacia*, which is abundant in the Loconia and San Nicola di Melfi stretches. This species, listed as a "Species of Union Concern" under EU Regulation 1143/2014 (European Parliament & Council 2014), represents a significant threat to native riparian ecosystems by altering floristic composition and reducing local biodiversity (Vítková et al. 2020). The management and progressive eradication of *R. pseudoacacia*, together with the gradual conversion of artificial plantations into native mixed forests, are priority measures to ensure the conservation of the river's ecological functionality, in accordance with European guidelines on invasive species management and habitat restoration.

Finally, *Phragmites australis* reed beds and helophytic communities in the lower course, though occupying a limited area, hold high ecological importance. The results confirm their role as functional wetland habitats, capable of providing refuge for species associated with fluvial ecosystems, facilitating natural phytoremediation processes, and mitigating hydrological fluctuations (Milke et al. 2020). These habitats are recognized under the Habitats Directive 92/43/EEC (European Council 1992) as habitats of conservation interest (code 72A0) and also contribute to achieving the objectives of the Water Framework Directive 2000/60/EC (European Parliament & Council 2000), which emphasizes the need to maintain or restore the ecological status of water bodies. However, the coastal zone experiences strong pressures from tourism-related urbanization, agricultural expansion, morphological changes to the shoreline, and the

discharge of nutrients and wastewater, leading to eutrophication and degradation of riparian vegetation, contrary to the provisions aimed at protecting coastal ecosystems.

Overall, the spatial distribution of habitats reveals a gradient of increasing naturalness upstream, with a predominance of riparian formations that play a central role in the ecological structure of the river landscape and a floristically significant enrichment in the hilly and mountainous stretches. Integrating the results with the European legal framework highlights the need to implement conservation and restoration strategies consistent with the Habitats Directive 92/43/EEC (European Council 1992), the Birds Directive 2009/147/EC (European Parliament & Council 2009), the Water Framework Directive 2000/60/EC (European Parliament & Council 2000), and EU Regulation 1143/2014 on invasive alien species (European Parliament & Council 2014), so that the entire river system can maintain or recover an adequate level of ecological integrity and ensure the protection of habitats and species of community interest along the Ofanto River.

Conclusion

The findings confirm that the Ofanto River represents a fluvial system of high ecological significance, with riparian habitats functioning as a key regional ecological corridor.

In order to ensure the conservation of biodiversity and the long-term functionality of the river system, integrated and targeted management actions are required. Priority measures include the re-naturalization of riverbanks and the reconversion of artificial plantations into native vegetation. Contemporarily, invasive species monitoring and control programs should be implemented, adopting ecologically sustainable management approaches. The protection and enhancement of residual habitats, such as reed beds, oak forests, and scrublands, constitute additional key nodes within the broader ecological network.

A further strategic aspect concerns the integration of agricultural, urban, and water management policies with ecological conservation goals, in order to preserve functional connectivity between fluvial ecosystems and surrounding landscapes.

In light of these findings, the Ofanto River can be considered a regional-scale ecological corridor linking lowland, hilly, and mountainous environments of southern Italy. Future research should focus on long-term vegetation monitoring, the assessment of climate change impacts on hydrological regimes, and the evaluation of the effectiveness of ecological restoration measures. The integration of remote sensing tools, ecological indicators, and participatory territorial management processes may provide the foundation for a sustainable conservation strategy for the river and its fluvial landscape.

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