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Mid-term report of case studies

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NATURA CONNECT

Mid-term report of case studies

M7 Interim Report on comparison of TEN-N implementation across case studies

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1. Introduction

The NaturaConnect project is a crucial initiative aimed at advancing the implementation of the Trans-European Nature Network (TEN-N). This milestone report compiles mid-term findings from the six case studies of the project, each serving as a critical testing ground to understand the practical implications of TEN-N across diverse environmental and socio-political contexts and different spatial scales. These mid-term reports represent a starting point for identifying commonalities and challenges among case studies, offering guidance on the design and implementation of TEN-N. This process will culminate in the production of Deliverable D8.3, a report comparing TEN-N implementation across case studies, by June 2026.

The primary objective of the case studies is to gain an in-depth understanding of local conservation planning challenges and to evaluate how TEN-N principles can be integrated into spatial conservation planning at multiple levels - local, national, and regional. The Danube-Carpathian transboundary region is the only regional case study, working with ten European and five non-European countries. Finland, France and Portugal are national case studies which work closely with national biodiversity and environmental agencies. The Doñana region and the Leipzig-Halle peri-urban floodplains are the two local sub-national case studies which involve a broad network of multi-actor governance and policy instruments. By aligning with the unique policy and planning needs of each area, case studies offer a valuable "reality check" on the feasibility and effectiveness of TEN-N implementation in different settings.

The unique objectives and expected outcomes of each case study are detailed in the "Case study objectives" section of the reports, preceded by the "Identification of conservation planning challenges" section, which outlines the specific geography and urgency of the conservation issues addressed. When available, the reports also provide a more detailed section on the local policy context and financial mechanisms, exploring existing policies on spatial conservation and how they may conflict or complement each other.

Engagement with a wide range of stakeholders is crucial across all case studies, as they are key actors in addressing the identified conservation planning challenges. These stakeholders include national environmental agencies, local administrations, protected areas managers, NGOs, and international commissions and conventions, such as those involved in the Danube region. Each report includes a section listing the specific stakeholders and decision-makers involved. Their engagement is essential for disseminating project results and supporting the implementation of TEN-N.

The "Methodological approaches and preliminary results" section provides detailed information on the sub-tasks and progress of each case study, including preliminary results from both quantitative and qualitative methods, where available.

By collating these individual reports, we aim to provide a comprehensive overview of the challenges, methodologies, and preliminary findings from each case study. This milestone not only reflects the progress made but also sets the stage for ongoing efforts to refine and implement effective conservation strategies under the TEN-N framework.

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2. Danube case study

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Abbreviations

CC – Carpathian Convention

DCR – Danube-Carpathian region

EUSDR – European Union Strategy for the Danube River

EUSDR PA – European Union Strategy for the Danube River Priority Area

HYMO TF – Hydromorphological Task Force

ICPDR – International Commission for the Protection of the Danube River

RBMP – River Basin Management Plan

RBM EG – River Basin Management Expert Group

TEN-N – Trans-European Nature Network

WFD – Water Framework Directive

WG – Working Group

WP – Work Package

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2.1. Identification of conservation planning challenges

The Danube-Carpathian region (DCR) comprises eleven EU Member States (Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Poland, Romania, Slovakia, Slovenia, Italy), and nine cooperation countries (Albania, Bosnia and Herzegovina, Kosovo, Moldova, Montenegro, North Macedonia, Serbia, Switzerland, Ukraine), see Fig. 1.

Figure 1. Map of the Danube-Carpathian region, ©WWF.

Fig. 2 represents the share of land per country in the Danube-Carpathian region.

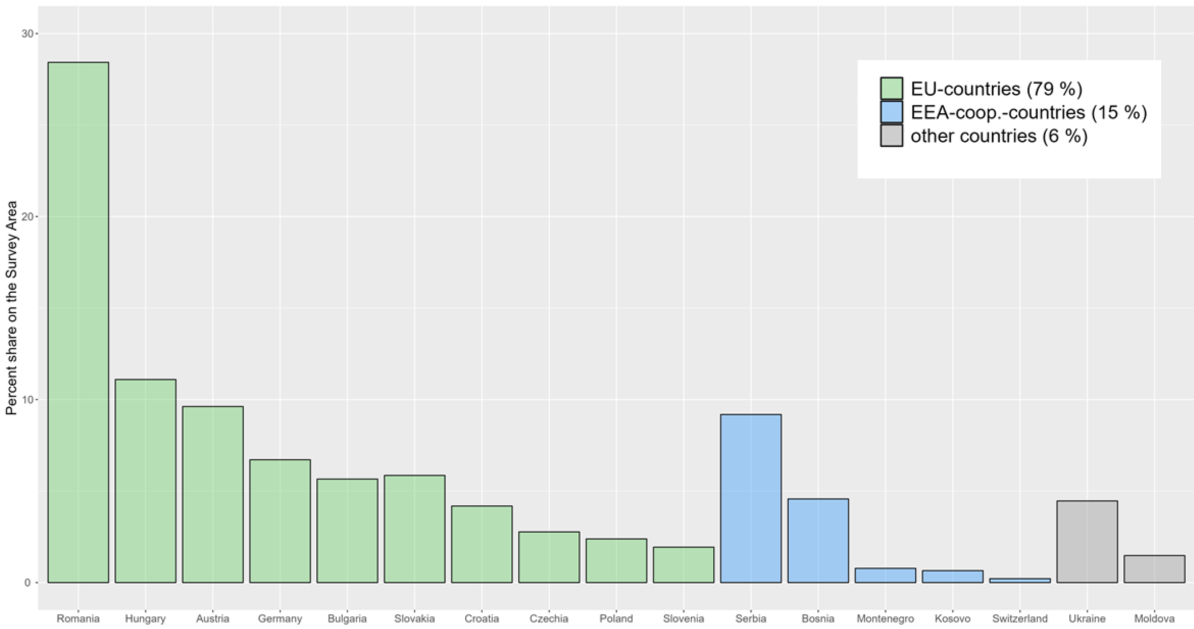

*Figure 2. Geopolitical units of the survey area (*without Albania, Italy and North Macedonia with a share of < 0.1%).*

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The area includes many of Europe's most spectacular wilderness areas and some of the largest remaining areas of virgin and natural forests, still unfragmented. They are home to two-thirds of the European populations of bears, lynx and *wolves*. The region includes most of Europe's last remaining intact rivers and wetlands, including the Danube Delta. It also shelters sturgeons that survived the end of the dinosaurs but now are on the edge of extinction. For thousands of years, this natural landscape has been shaped by its people, and thus bears incomparable wealth of history embedded in a cultural landscape.

However, this outstanding hotspot of biodiversity is under threat due to unsustainable economic development. New roads, urban development, intensifying agricultural and forestry practices, energy infrastructure, and tourism development are often planned and implemented without considering nature conservation, particularly protected areas and ecological connectivity. Land use changes and river regulations lead to the fragmentation of terrestrial and freshwater wildlife habitats. There are limited regulations and guidelines on how to safeguard green and blue infrastructure.

2.2. Policy context

The International Commission for the Protection of the Danube River (ICPDR) and the Carpathian Convention (CC) provide good cooperation platforms and so does the EU Strategy for the Danube Region (EUSDR). Representatives of relevant ministries, authorities and experts regularly meet to discuss strategies and action plans, inform each other about project implementation and results for sustainable development in the region.

All Parties of the CC and the ICPDR are signatory countries to the Convention on Biological Diversity (CBD); 10 out of 15 contracting countries are EU Member States, which committed to the EU Strategy on Biodiversity 2030. Both the Strategy and the CBD aim at the extension of protected areas and the establishment of an ecological network as parts of the Trans-European Nature Network (TEN-N).

In this context, in July 2022, the EUSDR Priority Area (PA) 4 'Water Quality', PA5 'Environmental Risks', PA6 'Biodiversity, Landscapes, Quality of Air and Soils', the Carpathian Convention, and the International Commission for the Protection of the Danube River (ICPDR) endorsed the Declaration "Achieving Functional Biodiversity in the Danube-Carpathian by Mainstreaming Ecological Connectivity". Thereby, the key regional actors reaffirmed their commitment to safeguarding ecological connectivity and biodiversity in the "Green Heart of Europe."

Furthermore, the ICPDR "emphasizes the significant potential for synergies with the EU Water Framework Directive, and the EU Biodiversity Strategy for 2030, especially with regard to the targets on protected areas, restoration and species/habitats conservation improvement and stress the need to strengthen cooperation with nature protection authorities" (Danube Declaration adopted at the ICPDR Ministerial Meeting, 8 February 2022).

ICPDR will release an updated Danube River Basin Management Plan (DRBMP) in 2027. The previous DRBMPs included a prioritization approach for continuity restoration in the Danube catchment, which, however, was limited to rivers with a catchment >4,000 km². The methodology of this Index could be updated and potentially extended by the lateral dimension (i.e., towards floodplains and sub-catchment areas) by the Danube-Carpathian case study. This possibility was already presented at two ICPDR Hydromorphology (HYMO) Task Group and two ICPDR River Basin Management (RBM) Expert Group Meetings in 2023. The decision on the approval and inclusion of the related method into the DRBMP 2027 will be decided at a later stage and due to the release of the DRBMP, might take place after finalization of the

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NaturaConnect project. However, ICPDR is continuously updated on the approach and is regularly given the opportunity to provide feedback and input.

The CC adopted the Carpathian Biodiversity Framework 2030 at its 7th Conference of the Parties, held in Belgrade, 11-13 October 2023. In the COP7 Ministerial Declaration, the Parties "acknowledge the importance of ecological connectivity for halting biodiversity loss and ecosystems degradation and the fact that the Carpathians form a natural bridge between western and eastern Europe for species migration and genetic exchange..." In collaboration with its observers, the Carpathian Convention Working Group on Biodiversity developed the International Action Plan on Conservation of Large Carnivores and Ensuring Ecological Connectivity, the Carpathian Strategy for Enhancing Biodiversity and Landscape Conservation Outside and Inside Protected Areas and in a cross-sectoral setting together with the Carpathian Convention Working Group on Sustainable Transportation, the Joint Strategic Action Plan 2021-2026 for the Implementation of the Protocol on Sustainable Transport. Ecological connectivity is a prominent subject for the Convention. Furthermore, the Convention encourages an active engagement of the Parties, stakeholders and relevant initiatives, such as the Carpathian Network of Protected Areas, in establishing a Trans-European Nature Network, as a coherent network of protected areas throughout Europe, one of the strategic actions outlined in the EU Biodiversity Strategy for 2030.

2.3. Case study objectives and expected outcomes

To identify conservation needs and vulnerability to land-use and climate, datasets from the EU Water Framework, Floods and Nature Directives, Copernicus Riparian Zones and other data generated under the two regional platforms (the ICPDR information System "DANUBIS" and the Carpathian Countries Integrated Biodiversity Information System "CCIBIS") will be integrated through data and modelling workflows and scenarios developed in WP3-5. TEN-N configurations of optimized protected areas and corridors (WP6-7) will be analysed and adapted to the regional transboundary context through consultation and co-design with the relevant stakeholders of various sectors (e.g., conservation administrations, agriculture or infrastructure). In particular, BOKU will test the connectivity and networks design (WP6) to provide an ecological prioritization of measures to restore river and habitat continuity in the Danube River Basin. Outputs will inform policies such as CC Action Plans for Sustainable Forest Management, connectivity conservation for large carnivores, freshwater conservation including the Danube River Basin Management Plan 2028-2033, and pledges for extension of protected areas in fulfilment of the EU Biodiversity Strategy for 2030, among others."

Excerpt from the Grant Agreement, slightly changed.

The general purpose of this case study is to foster transboundary and cross-border cooperation following a whole-of-government approach on planning TEN-N and projects/initiatives on ecological connectivity in line with the Declaration "Achieving Functional Biodiversity in the Danube-Carpathian by Mainstreaming Ecological Connectivity". The case study will present a potential methodology for securing an ecological network of green and blue infrastructure, including possible financing mechanisms. Both ICPDR and CC are continuously informed and involved in the development of this method. Thereby, we are engaging relevant expert groups working under the CC and the ICPDR to improve their knowledge base and address their needs for better implementation of policies, planning and management measures towards building the Trans-European Nature Network (TEN-N). However, its application and implementation in the DCR will not be part of the project.
The focus of the case study lies on transboundary, large-scale connectivity for aquatic and terrestrial species and habitats. The results should support the planning process related to

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blue and green infrastructure in the Danube-Carpathian region, including financing mechanisms and recommendations for governance.

The general objectives are:

- Facilitate a dialogue of stakeholders on building TEN-N based on existing planning instruments and ongoing work on connectivity, while increasingly using the results of the NaturaConnect consortium, in particular the prioritisation and connectivity analysis for this cross-border region;
- Support the Danube-Carpathian Region (DCR) by providing relevant insights into the integrated management and planning of ecological connectivity and biodiversity aspects through mainstreaming of NaturaConnect methodologies and results into the DCR;
- Engage with the Carpathian Convention (CC) and the International Commission for the Protection of the Danube River (ICPDR) to expand their knowledge base on ecological connectivity;
- Perform integrative analyses on multiple human stressors, biodiversity values & the current conservation status at different spatial scales in the DCR;
- Develop jointly a blueprint for a Trans-European Nature-Network (TEN) with the NaturaConnect consortium;
- Provide insights/results that support the implementation of multiple EU directives and strategies (WFD, Habitats Directive, EU Biodiversity Strategy etc.) in the DCR;
- Co-create and ask for input and feedback on NaturaConnect project deliverables, most importantly related to green and blue infrastructure, e.g., WP6 Connectivity Guidelines or WP2 Review;
- Build capacity on planning instruments (link to WP6 and W7) for integrating blue and green infrastructure into TEN-N as well as cross-cutting topics like stakeholder engagement, awareness raising and communication (link to WP1);
- Compile recommendations on how to improve governance of integrated blue and green infrastructure including financing.

Carpathian Convention (CC)

- Support the development and implementation of the Carpathian Convention Biodiversity Framework with knowledge and input from NaturaConnect.
- Organise cross-sectoral workshops to build capacity on planning instruments and funding opportunities for ecological connectivity, and to develop recommendations.

International Commission for the Protection of the Danube River (ICPDR)

- Support revision of the Danube River Basin Management Plan (DRBMP) with a focus on biodiversity.
- Provide suggestions for improving ICPDR's ecological prioritisation approach for continuity restoration and for extending it to the lateral dimension (i.e., toward floodplains), potentially also including biodiversity aspects.

Working along with the two main treaties in the Danube-Carpathian region, expected outcomes are improved planning, governance and financing for the establishment of TEN-N by providing the following:

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Data

- GIS-database for the Danube-Carpathian region incorporating existing spatial datasets;
- Calculation of connectivity parameters at different spatial scales (e.g., river segment, riparian zone, protected areas, sub-catchments) that are relevant to management and decision making to identify relationships between different data sets and their accuracies, management units etc.;
- Integrative analysis of multiple stressors, biodiversity values, protected areas, connectivity and conservation needs in freshwater and terrestrial realms in the case study area (according to Seliger et al. 2015 and Schinegger et al. 2018).

Tools

In close cooperation with WP1, WP6, and WP7, practicable tools will be made available for the respective target groups in the region.

- Map of the Danube-Carpathian region indicating the network of blue and green infrastructure and potential restoration areas;
- Training – Learning platform (WP1);
- ArcGIS, QGIS, R packages (WP6);
- Connectivity Guidelines (WP6);
- NaturaConnector (WP7).

Recommendations

Based on the research of BOKU and WP2, and consultations with the task forces, expert and working groups of ICPDR and CC, recommendations will target gaps and suggest improvements to the current process of TEN-N and the implementation of the Carpathian Biodiversity Framework.

- Recommendations for the improvement of the ICPDR prioritisation approach for continuity restoration in the Danube catchment. The current index could be extended by the lateral dimension (i.e., towards riparian zones and the floodplains) and by biodiversity aspects;
- Recommendations for the design of a TEN-N in the case study region (e.g., methodological approach on how to select potential areas, input of relevant criteria etc.);
- Recommendations on funding mechanisms for the implementation of TEN-N;
- Policy recommendations towards the improvement of protected areas and connectivity governance.

Format (publications, reports, software)

The first planned publication will focus on the above-described analyses related to Natura 2000 areas and riparian zones within the case study region. Once finalised, the R-code and Python script of our analyses can be provided.

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2.4. Stakeholder engagement

Stakeholders involved

Two main types of stakeholders have been identified by the case study team as playing a role in establishing TEN-N in the Danube-Carpathian region. Firstly, those involved in nature conservation or its regulation, and secondly those involved in land use (agriculture, forestry, etc.) and development (transport and energy infrastructure, etc.). Ideally, those sectors collaborate for the best solutions integrating the needs for biodiversity, ecosystem services, ecological connectivity and with it, human welfare.

Actors at the transnational level in the Danube-Carpathian region

There are three international treaties in the DCR, all of which commit to sustainable development of the region which comprises a balance of social, economic and environmental aspects. In the following the International Commission for the Protection of the Danube River (ICPDR), the EU Strategy for the Danube Region (EUSDR) and the Carpathian Convention are briefly described.

International Commission for the Protection of the Danube River (ICPDR)

The International Commission for the Protection of the Danube River (ICPDR) is a transnational body established in 1994 to implement the Danube River Protection Convention (DRPC), the major legal instrument for cooperation and transboundary water management in the Danube River Basin. It works to ensure the sustainable and equitable use of water in the Danube River Basin. The ICPDR is the platform responsible for the implementation of all transboundary aspects of the EU Water Framework Directive and Floods Directive.

The ICPDR is formally composed of the Delegations of all Contracting Parties to the Danube River Protection Convention and is assisted by a permanent secretariat including technical experts. The technical work is carried out in the Expert Groups composed of national experts from the Contracting Parties and representatives from ICPDR observer organisations.

The most relevant Expert Groups related to ecological connectivity are

- Hydro-morphology Task Group (HYMO TG) and the
- River Basin Management Expert Group (RBM EG).

While Observers are not granted decision-making rights, they actively participate in all meetings of the ICPDR experts and task groups, as well as plenary meetings. Delegates of Observers have access to information including all technical meeting documents and the right to contribute to all technical discussions.

EU Strategy for the Danube Region (EUSDR)

Countries of the Danube region supported by the EU established in 2010 the European Union Strategy for the Danube Region (EUSDR), identifying common needs, challenges and opportunities that can be fully exploited only in cooperation to boost regional cohesion.

EUSDR's mission is to protect nature and people, build a prosperous region with a healthy environment, equal societies and high living standards, create sustainable jobs and open fair opportunities from the Black Forest to the Black Sea. It is meant to provide platforms of exchange, guidance and networking, coordination of policies and joint actions.

The Commission´s Directorate General for Regional Policy helps to implement the Strategy by facilitating and supporting the actions of the participating countries. The High-Level Group

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(HLG) on macro-regional strategies is made up of official representatives from all countries involved. It assists the Commission in the policy coordination of the Strategy.

The National Coordinators (NCs) have a strategic coordination function within their national or regional government. The NCs coordinate and keep an overview of the participation of their country in the implementation of the EUSDR including all Priority Areas.

The Danube Region Strategy addresses a wide range of issues; these are divided into 4 pillars and 12 Priority Areas (PAs). Each Priority Area is managed by at least two countries as Priority Area Coordinators (PACs) and assisted by the Danube Strategy Point. The PACs organise Steering Group meetings in which mainly the representatives of the ministries of foreign affairs of the Danube countries participate along with other stakeholders as observers.

The most relevant priority areas for ecological connectivity are included in the Environmental Pillar composed of Priority Area 6 'Biodiversity, Landscapes, Quality of Air and Soils', PA 4 'Water Quality' and PA5 'Environmental Risks'. Also, PA1b Road & Rail and PA1a Navigation are relevant.

The Danube Civil Society Forum is the platform for civil society dialogue and networking in the Danube basin under the EU Strategy for the Danube Region (EUSDR). It functions as the interface for structured consultations between civil society and public and private authorities on the regional, national and EU levels as well as to international and intergovernmental organisations active in the region.

The Danube Civil Society Forum is dedicated to supporting civil society organisations in the Danube basin. It aims to promote and enhance civil society participation and networking in the framework of the European Union Strategy for the Danube Region.

The Carpathian Convention (CC)

The Framework Convention on the Protection and Sustainable Development of the Carpathians (Carpathian Convention) unites the 7 Carpathian countries of Central and Eastern Europe in a unique partnership, providing a transnational framework for cooperation and multisectoral policy integration. It is an open forum for stakeholder and public participation and a platform for developing and implementing transnational strategies, programmes and projects for protecting and sustainably developing the region. The Convention was signed in 2003 and ratified in 2006 by all 7 Parties. It is the only multi-level governance mechanism and international legal framework that covers the entire Carpathian region. In addition, it is the second sub-regional treaty-based regime for the protection and sustainable development of a mountain region worldwide, following the Alpine Convention.

The following bodies are relevant:

- Secretariat of the Carpathian Convention;
- Carpathian Convention Implementation Committee (country focal points from the Carpathian ministries of the environment);
- CC Working Groups of Biodiversity, Forestry, Sustainable Transport, and Sustainable Agriculture comprising representatives of the respective ministries and observers (research institutions, NGOs, consultants, interested groups, representatives of other relevant projects in the region).

Protected area networks

The members of the various protected area networks play an important role in developing and implementing nature conservation projects also related to ecological connectivity. Their protected areas represent core areas for the future TEN-N. Some administrations were project partners in connectivity projects and bear the technical know-how and experience in identifying

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and monitoring ecological connectivity in the field. Their strength is their knowledge and eagerness to improve the conservation status of their protected area and are close to local players.

- Members of the Danubeparks, which bring together national and nature parks, biosphere and nature reserves from nearly all the Danube countries including Romania, Moldova, Bulgaria, Serbia, Croatia, Hungary, Slovakia, Austria, and Germany
- Members of the Carpathian Network of Protected Areas (CNPA; park administrations from the 7 Carpathian countries)
- Members of the EUROPARC Federation, the protected area network for the entire of Europe, in and outside the EU
- Members of Parks Dinarides, based in Montenegro and comprising 100 protected areas in the Dinaric Arc
- Members of ALPARC, the network of protected areas in the Alps; collaborate and support the CNPA

NGOs active in the case study area

Both globally and nationally active organisations (e.g., BirdLife, WWF, Greenpeace) are committed to nature conservation and related policy and advocacy work, but also to awareness raising of civil society, including youth. They are also committed to scientific research and fieldwork. The NGOs act as watchdogs and can draw the public's attention to environmental problems. They are important drivers of the topic, support governments, and mediate between the sectors, but are often opposed or ignored. Representatives of the economic sectors perceive them as 'green dreamers', meaning their claims are unrealistic (workshop result, TRANSGREEN Kick-off Meeting, 2017).

Actors at the national level

It is obvious from the number and diversity of players involved that the topic requires a complex approach to achieve concrete implementation of the ecological network at the national level. There are many interests in land use and management. There is no guarantee of completeness for actors listed in the following since the NaturaConnect team engaged mainly with actors on the transnational level representing their governments. In addition, all 15 analysed countries have their particularities in governance and law enforcement.

National public authorities/institutions:

- Ministries of the environment, agriculture, forestry, spatial, urban and land use planning, rural development, water management, transport, tourism and energy
- Regional governments responsible for the environment, agriculture, forestry, spatial, urban and land use planning, rural development, water management, transport tourism and energy like in Austria and Germany
- Regional and local agencies for nature conservation and protected areas like in Romania
- Spatial planning and rural development institutions
- Forest management institutions
- Water management institutions

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- Chambers of agriculture, forestry, etc.
- Public service providers related to transport and energy infrastructure
- Municipalities, local communities

Interest groups:

- Landowners
- Farmer associations
- Hunting and fishing associations
- Industry
- Tourism organisations
- Companies
- Academia
- NGOs
- Media
- Citizens

To simplify, the actors per sector are described jointly in the following:

Environmental actors

The ministries of the environment of each country are important players when it comes to decision-making. They work on new laws or frameworks for nature conservation. Many interviewees agree that their influence is limited compared to other ministries. Most countries have a protected area and/or a nature protection agency, either embedded in the ministries of the environment or as a separate entity. In Austria and Germany, the federal states are responsible for nature conservation in their territory, making it difficult to have a joint vision and direction of activities. However, the interviewees agreed that most agencies have insufficient funding and capacity to cope with the wide portfolio of tasks, including administration. 'There are a bunch of people in Bucharest in the office. They basically issue permits. In the field, two or three people per county are in charge of managing tens of Natura 2000 sites. In many cases, there are no funds for field trips, monitoring and other key elements that should be part of the management' (interview, Romania).

The European legislation framework concerning nature conservation gives organisations and persons the right to submit complaints to the European Court when serious implementation failures occur (for example building an illegal ski resort in the Pirin National Park in Bulgaria). In this way, the Lech Valley, a natural jewel in Austria could be saved from the construction of river dams and is now a sustainable tourism destination. European legislation is a powerful tool for nature conservation at the national level. With the help of the European Court of Justice, non-transparent dealings at the national level can be revealed and stopped.

Other actors and their relationship to nature conservation

According to the participants in the interviews, surveys and workshops, the main sectors impacting conservation/ecological connectivity/TEN-N are agriculture, forestry and energy, followed by transport, water management and industries (mining), and the main stakeholder groups are landowners and communities (Fig. 3).

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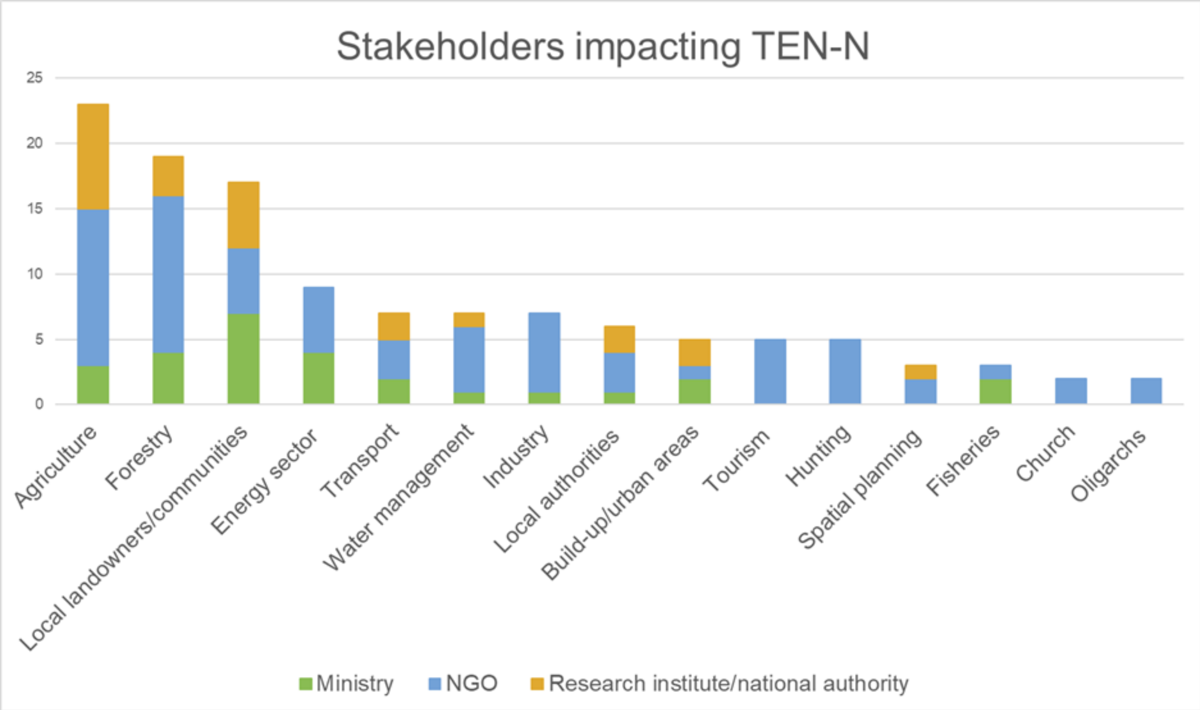

Figure 3. Stakeholders impacting TEN-N; results of 43 interviews conducted during spring 2023 until spring 2024.

A thorough discussion about the various stakeholders including the opinions of interviewees from different fields of nature conservation (ministries, national authorities, research institutions, and NGOs) can be found in Deliverable D2.1 Review and synthesis of best practices in governance and land-use policies to implement TEN-N which will be available on the NaturaConnect website very soon.

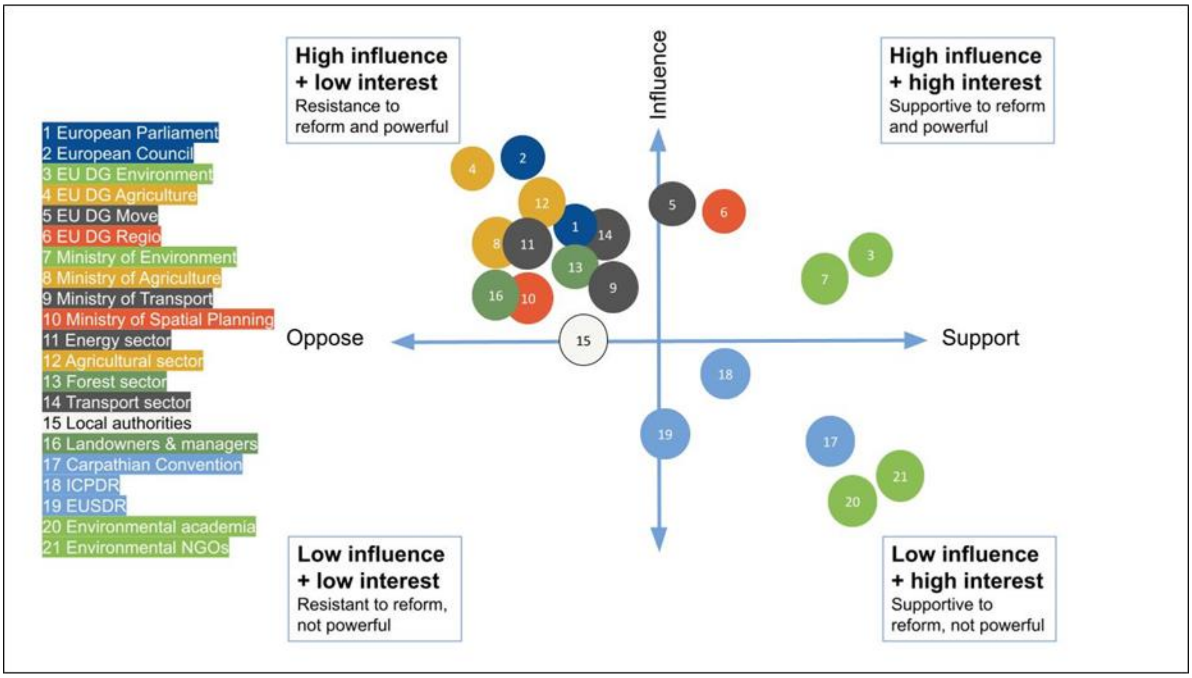

Figure 4. Stakeholder matrix for the Danube-Carpathian region based on workshops and discussions, WWF-CEE.

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The above-mentioned groups are committed to implement the EU Biodiversity Strategy for 2030 and the Global/Carpathian Biodiversity Framework and their targets related to the increase of protected areas to 30% of their country, whereas 10% strictly protected and the establishment of an ecological network.

Through regular meetings, workshops and seminars we discuss NaturaConnect related topics. Representatives bring the new findings, tools and discussed solutions back to their respective ministries. This enables us to place the NaturaConnect instruments, findings and recommendations at the national level in the region. Whereas ICPDR task forces and expert groups' work leading to the new strategies or action plans, e.g., the DRMB, are of binding nature, this mechanism does not exist for the Carpathian Convention.

There is a certain chance of involving representatives from other sectors in the process, which of course depends on their willingness. There are working groups in the ICPDR and the EUSDR that are dedicated to economic issues such as hydropower or transport. The team is also trying to involve these groups with varying degree of success.

Stakeholder engagement

The NaturaConnect case study team engages with relevant stakeholders under the umbrella of the CC and the ICPDR and use these platforms for interactive workshops, exchange of knowledge, data and experience, and feedback to draft NaturaConnect deliverables as mentioned above in the Outcome section.

To effectively engage with the stakeholders, the project deliverables need to be understandable for the policy context. WWF-CEE and BOKU get in contact with the respective work package leaders to prepare for the workshops and consultations. The project takes up feedback and input to the following deliverables:

- WP1 NaturaConnect Learning Platform;
- WP1 Training Needs Assessment;
- WP2 Review and synthesis of best practices in governance and land-use policies to implement TEN-N;
- WP2 Factsheets on public, private and blended financial support options for TEN-N and recommendations for each case study;
- WP6 Guidelines for connectivity conservation and planning in Europe;
- WP6 Map of integrated blue and green infrastructure;
- WP7 NaturaConnector;
- In general, discussions around TEN-N scenarios and related topics like models for conservation and restoration values for corridors, multi-functional connectivity and more;
- Effective communication of NaturaConnect activities and possibilities for engagement in collaboration with the secretariats of the ICPDR and the CC.

WWF-CEE engaged with CC and provided valuable input to the development of the Carpathian Biodiversity Framework, which was adopted at the 7th Conference of the Parties (COP7) in October 2023.

The COP7 Ministerial Declaration and Decisions welcomes the approval of NaturaConnect and encourages the countries to collaborate, support the project implementation and promote the project results to contribute to the implementation of the Carpathian Biodiversity Framework.

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The project organised two important workshops, which brought together ministerial representatives of the seven Carpathian countries, representatives of the Convention for Biodiversity, IUCN, and UNEP as well as observers working in science or on related projects, NGOs, consultants and others. A one-and-a-half-hour workshop on the NaturaConnect project was held at the 14th Meeting of the Biodiversity Working Group of the Carpathian Convention (Vsetín, Czech Republic, 22-24 May 2023), and a one-and-a-half-hour stakeholder consultation at the 7th Carpathian Convention Conference of the Parties (Belgrade, Serbia, 11-13 October 2023). Altogether, approximately 70 people from 13 countries were engaged.

The main aim of the two events was to reveal dynamics on the current situation of connectivity implementation in the Carpathians. Workshop participants discussed the main barriers (socio-economic, legislative gaps, sectors) and enablers for the implementation of a well-connected protected area network in and between the countries of the region, and good practices to stakeholder engagement for the implementation of a well-connected protected area network between the countries of the region. Another question was about how countries work together on this subject and on financial aspects. Participants of the Stakeholder Consultation at COP7 talked about the needs of the Parties of the Carpathian Convention to foster the development of a functional ecological network in the region and how the Carpathian Convention can contribute to filling in the gaps.

The results of the two events will support the analysis for the WP2 Review and synthesis of best practices in governance and land use to implement TEN-N.

2.5. Methodological approaches

“In the Danube-Carpathian Transboundary region, NaturaConnect will build on, and extend, the methodology used for assessing connectivity in the Interreg projects ConnectGREEN (lead: WWF-RO) and MEASURES (lead: BOKU), which identified core conservation areas and ecological corridors for terrestrial carnivores and migratory fish species in the region, respectively.

The project will also build on models for cross-sectoral cooperation on the topic of preserving and restoring green infrastructure developed in another Interreg project SaveGREEN (lead: WWF-CEE). An extensive network of stakeholders has been built during these projects, therefore providing a solid basis for the implementation of the participatory engagement framework in the region.”

Excerpt from the Grant Agreement

Scientific method

A key focus here is leveraging and advancing existing planning tools and ongoing work in terms of ecological connectivity planning, e.g., to extend ICPDR’s existing freshwater ecological prioritisation approach into lateral dimensions, like floodplains and ecologically sensitive terrestrial habitats, thus advocating for restoration across realms. To define relevant criteria for the lateral extension, existing areas with high biodiversity and high restoration value are determined, to understand which environmental factors influence biodiversity in a positive or negative way. For this, we created a database with different spatial and tabular datasets related to river waterbodies (ICPDR River Basin Management Planning data, e.g., ecological and hydro-morphological status), land cover (CORINE), wetland ecosystems (EEA-extended wetland ecosystems) or riparian zones (Copernicus Riparian Zones) and from previous Interreg projects conducted in the DCR (Fig. 5).

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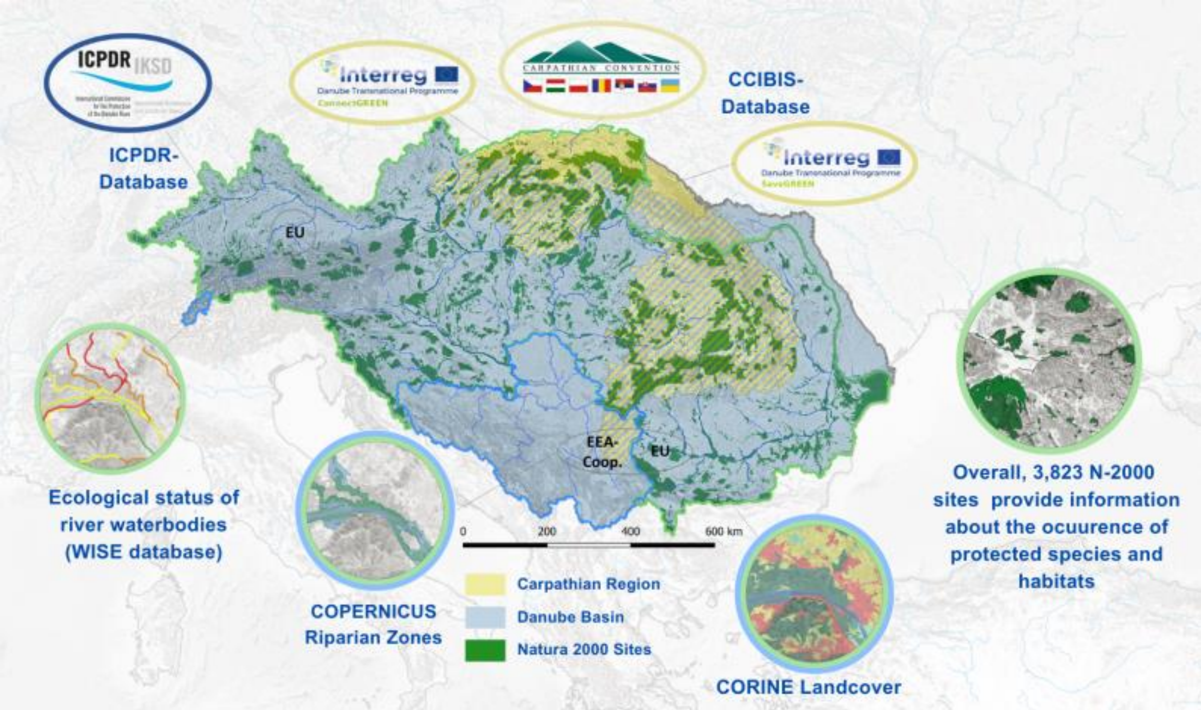

Figure 5. Spatial availability of datasets integrated in the analysis: EU countries (green), EEA cooperating countries (light blue), Danube River Basin (dark blue), Carpathian Region (yellow). In addition, the analytical framework: Analysis of the connection between species diversity and environmental conditions on three different scales (whole Natura 2000 sites, riparian zones, river waterbodies).

Starting points for the analysis build the Copernicus Riparian Zones which represent a first common denominator and a transition zone between freshwater and terrestrial ecosystems. They are strongly influenced by both stream water but also land use in the surrounding catchments. Since they provide a range of riparian functions and ecosystem services (as e.g., shown by Funk et al. 2021) they are important for the achievement of several European legal acts (e.g., EU Biodiversity Strategy, Habitats and Birds Directive, Water Framework Directive). However, they are highly impacted, restricted in terms of their expansion and dynamics and often exposed to conflicting goals – especially when it comes to floodplain restoration and conservation (e.g., Weigelhofer et al. 2020). In a first step we identified areas with high amount of actual riparian zone with in the potential riparian zone and calculated different parameters which related to landcover like the amount of natural land use from the Copernicus riparian zone land use layer inside the riparian zones and with the Corine landcover outside the riparian zones. This analysis was done on Hydro-basin level 12 provided by Lehner & Grill, 2013.

Due to the lack of biodiversity data covering a large proportion of the case study area, we decided to start our analyses by focusing on occurrence data of protected species within Natura 2000 sites. Overall, 638 species are listed in Natura 2000 sites of the Danube-Carpathian region. Since related data are only available for European countries, the biodiversity in EEA cooperating countries is currently not covered by this dataset. In combination with the CORINE Landcover data and the WISE database (including the ecological status of river water bodies), several variables were calculated at three different spatial scales (i.e., river water bodies within the Natura 2000 site, riparian zones within the Natura 2000 site and the entire Natura 2000 site; see also Fig. 5). These are listed in Fig. 6.

We overlaid species diversity data with environmental variables calculated on three different scales, and further basic statistical modelling approaches like linear regression and regression trees, as well as advanced methods like random forest and boosted linear regression, were applied to determine the drivers of species and habitat diversity in Natura 2000 sites.

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Additionally, to the analysis of Natura 2000 sites, we also used spatial datasets from Article 17 of the Habitats Directive (HD) and Article 12 of the Birds Directive (BD) with a resolution on 10 x 10 km² to determine hotspots for freshwater- and wetland related species and habitats. We identified freshwater- and wetland habitats listed in Annex 1 of the HD that occur in the EU-countries of the DCR (DCR-EU). Furthermore, we identified species from the annexes of BD and HD that are associated with freshwater and wetland habitats using an existing classification of the EEA (Petechsi et.al., 2015). The Rarity-Weighted-Richness (RWR) algorithm was used to determine hotspots of freshwater and wetland related species and habitats. This is an adequate and easily understandable prisonization approach which gives higher weights to rare features than to common features (F. Albuquerque & Beier, 2015; F. S. D. Albuquerque & Gregory, 2017). To identify hotspots, we selected the top 15 % of cells with the highest RWR value for species and the highest one for habitats and merged them. The 15 % threshold was already used by other studies to identify hotspots for different species groups (F. S. D. Albuquerque & Gregory, 2017; Rey Benayas & De La Montaña, 2003). Also, tabular data reported under Article 12 and 17 of the BD and HD were used to identify the conditions of species and habitats as well as pressures that act on them. The assessed conservation status of habitats and species is available on biogeographical level, so we extracted these assessments for all biogeographical regions that overlap with the DCR. Therefore, we used the parameter “Structure and Function” for habitats and “Habitat for Species” for the species.

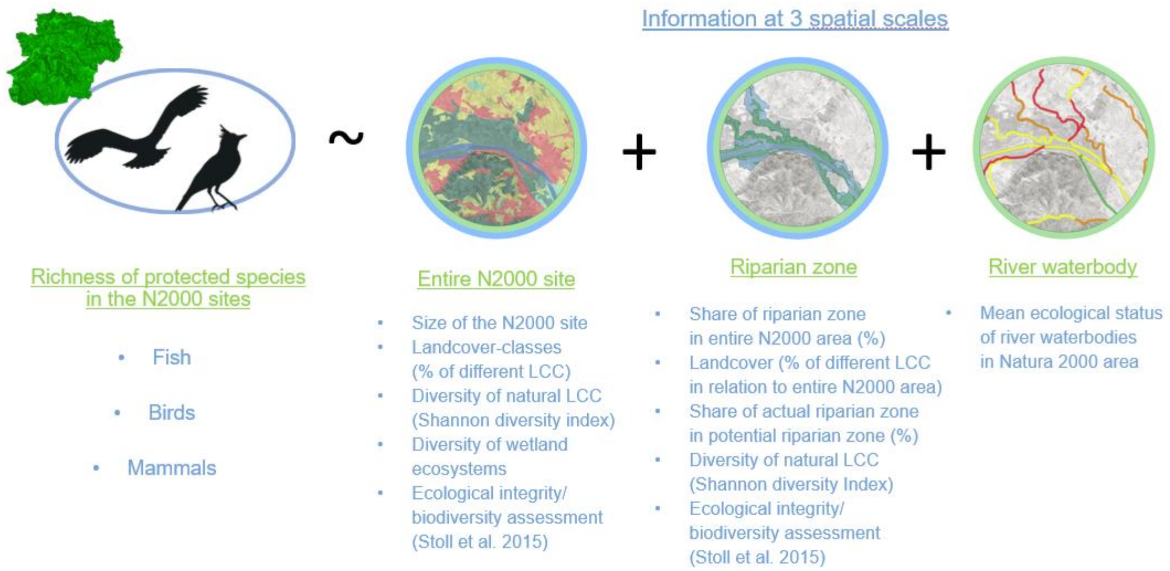

Figure 6. Parameters assessed at different spatial scales related to Natura 2000 areas.

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2.6. Preliminary results: opportunities and challenges

In this reporting period, the NC case study team introduced ICPDR, CC and EUSDR to the project and laid out the basis for collaboration.

BOKU collected data available in the region as basis for the development of the blue and green infrastructure, made a first assessment and started collaborating with ICPDR on developing the methodology for assessing stressors and identifying restoration areas.

Analysis of environmental conditions in the hydro-basins

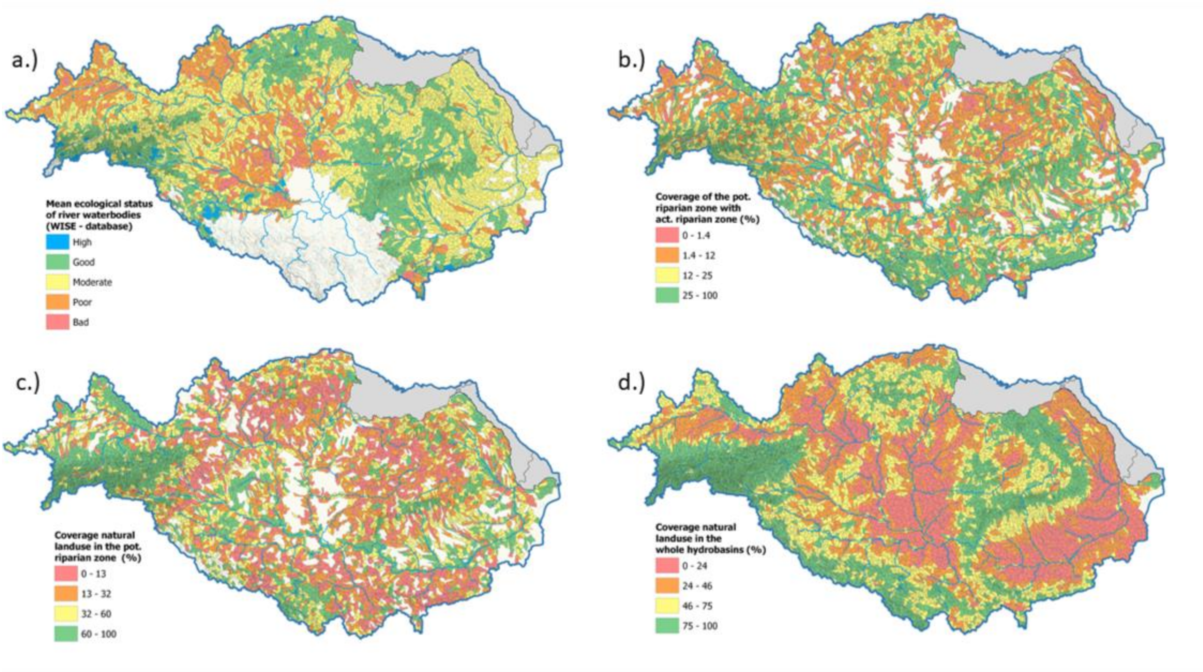

Figure 7. Preliminary analysis results: mean ecological status of river water bodies in the hydro-sheds of the DCR-EU. (a) The percentage covered by actual riparian zone in the potential riparian zone, (b) coverage of natural land-use in the riparian zones, (c) the amount of natural land-use including the hinterland, and (d) in the DCR-EEA.

The first analysis of the environmental conditions in the hydro-basins show that the mean ecological status of river waterbodies derived by the WISE-database is better in alpine areas with higher elevation. Along the bigger rivers the status of the river waterbodies is mostly moderate to poor. Similar patterns are visible in the analyses of land-use in the hydro-basins (including the hinterland). Especially hydro-sheds along the bigger rivers have high amount of artificial (e.g., agricultural) land-use. In comparison the western areas, in the Alps have on average more amount of natural land use. Also, the amount of natural land use and the percentage of actual riparian zone in the potential riparian zone is higher in these western areas. In contrast to the land use in the whole hydro-basin, areas with comparable high amount of natural land use in the riparian zones can also be found in the lower course of the Danube.

Freshwater and wetland related habitats and species in the DCR-EU

Throughout the study area there are 33 different habitat types listed in Annex I of the HD that are associated with freshwater and wetlands (standing water bodies (7), watercourses (6), wet grassland (6), mires bogs and fens (10), wet forests (4); Table 1). Of the total of 278 species associated with freshwater and wetland habitats, 118 (42%) are listed in the BD and 160 (58%)

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in the HD. Of the non-bird species, fish make up the majority with 49 species (31%) and invertebrates with 43 species (27%). In addition, 25 amphibian species (16%), 23 plant species (14%), 15 mammal species (9%) and 5 reptile species (3%) are listed in Annex II, IV or V.

Hotspots for freshwater and wetland related habitats and species in the DCR-EU

The results of the hotspot analyses show that the greatest diversity of freshwater and wetland habitat species can be found along the larger rivers. The situation is similar for diversity of habitat types. In many areas, habitat and species hotspots overlap with Natura 2000 sites. The overlap with Natura 2000 sites is particularly evident in the lower reaches of the Danube and is most visible in the Danube Delta. However, there are also some hotspots that are not protected or only protected by very small Natura 2000 sites. This is clearly visible in the upper reaches of the Danube in southern Germany and western Austria. Significant differences in the distribution of hotspots along national borders can be explained less by topographical or natural changes and more by differences in reporting methods and data quality in the EU Member States. In the case of habitat hotspots, this is particularly evident at the Romanian border. For the analysed species, the divergence in the data of the respective countries is particularly visible at the Polish border (in the north of the study area) (Fig. 8).

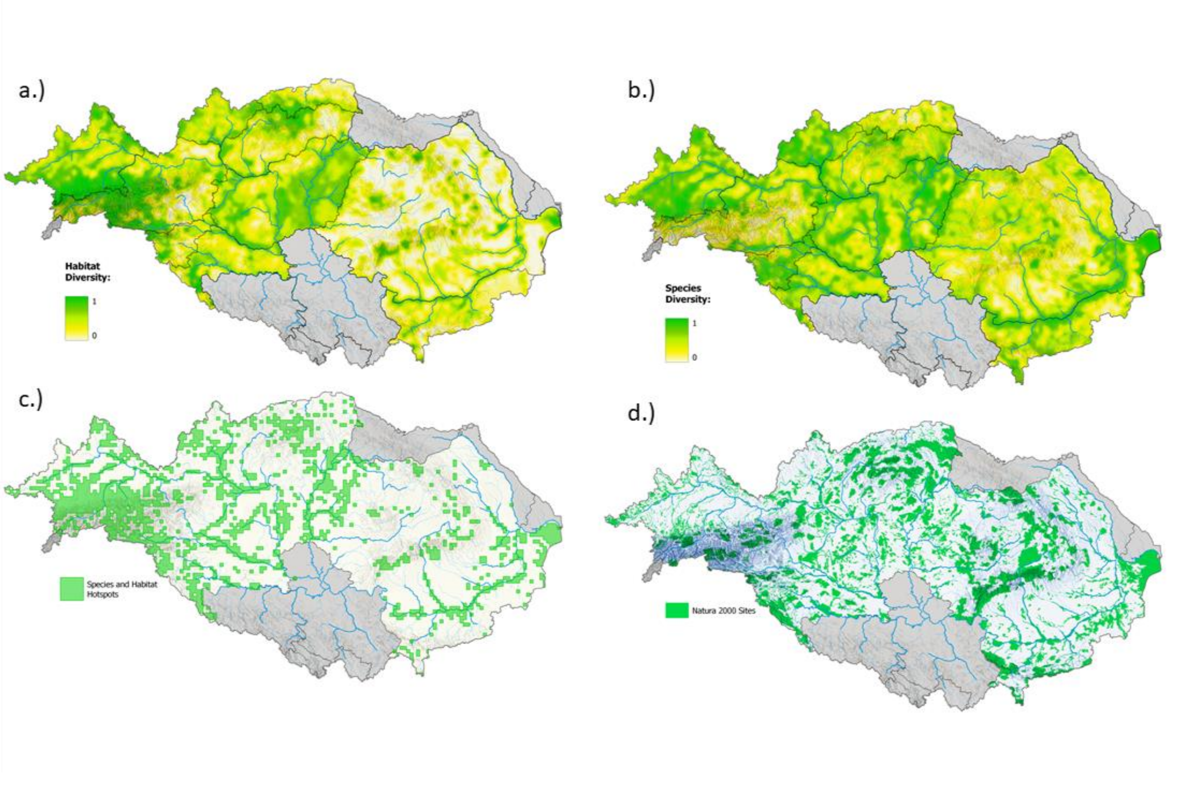

Figure 8. Preliminary results: Varity Weighted Richness (scaled from 0 to 1) for wetland and freshwater related habitats (a) and species (b) in the DCR-EU territory based on the EEA spatial dataset reported under Article 12 of the Birds Directive and Article 17 of the Habitats Directive. As well as the freshwater and wetland Hotspots (cells with the top 15 percent values for habitat or species diversity) (c) and Natura 2000 sites (d).

Status of freshwater and wetland related habitats and species in the DCR-EU

The status of freshwater and wetland habitats assessed based on the Art. 12 and 17 reports is mainly bad, poor or unknown, particularly in the Alpine, Continental and Pannonian regions. In the Alpine region, 16 % of habitats are classified as bad (U2), 30 % as poor (U1), 34 % as

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unknown (XX) and only 20 % as good (FV). The classification of habitats in the continental region (U1: 31.0%; U2: 36.7; XX: 14.6%, FV: 17.7%) and the Pannonian region (U1: 37.5%; U2: 42.9%; XX: 3.6%; FV: 16.1%) is similar. The three regions mentioned above cover most of the study area with around 94%, while the Steppic region and the Black Sea region together cover only around six percent. The conservation status of the habitat types is better in these two regions. Particularly striking is the bad or poor assessment of the status of watercourses, raised bogs, fens and marshes in the Alpine and Continental regions. The assessment of standing waters is slightly better in the Alpine region, but largely bad and poor in the Continental and Pannonian regions. The classification of wetland forests and meadows is also predominantly bad, poor or unknown in most regions. An overview of conservation status by region and habitat type or habitat type group is shown in Table 1.

Table 1. Status of habitat types in the Alpine (ALP), Continental (CON), Pannonian (PAN), Steppic (STE) and Black Sea (BLS) regions

Habitat type	Habitat-Code	ALP	CON	PAN	STE	BLS
Standing waters	3130	FV	U1	U2	FV	FV
	3140	U1	U2	U1	FV	FV
	3150	XX	U2	U1	FV	XX
	3160	FV	U1	U1	FV	
	3180	U1	FV			
	3190	FV	U2			
	31A0			U2		
Running waters	3220	U1	U1			
	3230	U2	U2			
	3240	XX	U1			
	3260	U1	U1	FV	FV	U1
	3270	XX	U1	FV	FV	FV
	32A0	U1	U1			
Wet grassland	1310		U1		FV	XX
	1340	FV	XX	U1		
	1530		XX	U1	FV	XX
	6410	U2	U2	U2	FV	FV
	6420	U2	U2			U1
	6440	FV	U2	U2	FV	FV
	7110	U2	U1	U2		

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Mires bogs and fens	7120	U2	U2			
	7130	U2				
	7140	U1	U1	U2		
	7150	XX	XX			
	7210	XX	U1	FV		
	7220	XX	U1	FV		XX
	7230	XX	U2	U2		
	7240	U1	XX			
	91D0	XX	U1	U1		
Wet Forests	91E0	U2	U2	U2		FV
	91F0	U2	U2	U2	U1	FV
	92A0	XX	U1	U1	FV	FV
	92D0	XX	FV		XX	XX

Most species (excluding birds) with a focus of occurrence in freshwater and wetland habitats show a bad, poor or unknown conservation status in most regions. In the continental region, only 29% of species are classified as good (FV), while 46% are classified as poor (U1), 14% as bad (U2) and 11% as unknown (XX). The classification is similar in the Alpine region (FV: 24%; U1: 8%; U2: 52%; XX: 16%). In the Pannonian region (FV: 44%; U1: 6%; U2: 46%; XX: 3%), the steppe region (FV: 51%; U1: 4%; U2: 34%; XX: 11%) and the Black Sea region (FV: 61%; U1: 4%; U2: 18%; XX: 18%), the classification is more positive. A detailed classification of the individual species groups in the respective regions is shown in Fig. 9.

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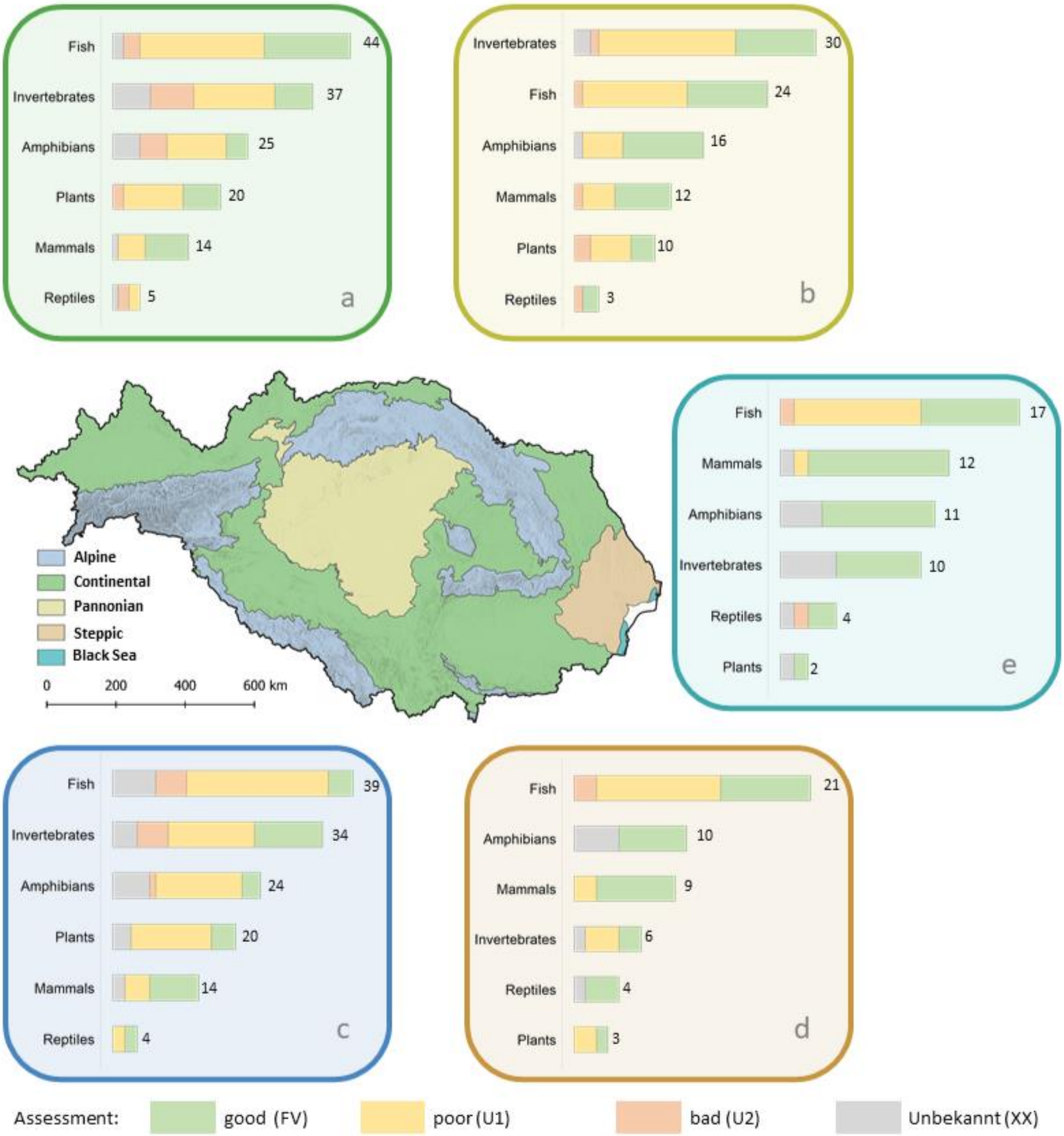

Figure 9. Status of the habitats of the species groups in the bioregions Continental (a), Pannonian (b), Alpine (c), Steppic (d) and Black Sea (e).

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Pressures on freshwater and wetland related habitats and species in the DCR-EU

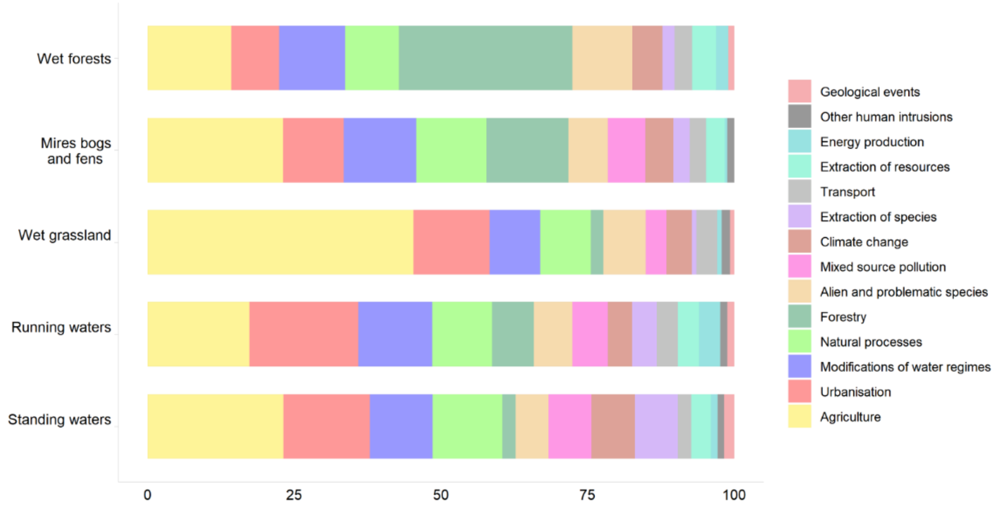

Figure 10. Preliminary results: Main pressures on groups of Freshwater and wetland related habitats.

A first analysis of pressures on freshwater- and wetland-related habitats extracted from data reported under the Article 17 of the HD shows that the majority of pressures that act on freshwater and wetland related habitats listed in annex I of the HD are related to agriculture (Fig. 10). Most pressures that act on running waters are related to urbanization and for wet forests most of the pressures are related to forestry. Also in the other habitat groups urbanization is a significant high source of pressures. Likewise, many pressures that act on all habitats come from modification of water regimes.

Further opportunities and challenges:

- First results have been submitted in the journal "Wasse und Abfall" in German language (Condition of species and habitats in the DCR-EU; Diversity for freshwater and wetland related species and habitats);
- Another scientific paper is in progress and will be submitted soon (hotspots calculated rarity-weighted-richness of species and habitats in the DCR-EU; comparison of these hotspots with layers derived by remote sensing; pressures that act on these species and habitats; pressures that act on Natura 2000 sites within water and wetland related hotspots);
- Create a link collected data (land-use, riparian zones, ecological status of river waterbodies etc.) with results from the analyses of Article 12 and Article 17 datasets;
- Implementing data from the ICPDR in the analysis (comparing results from article 12 and Article 17 data with data regarding hydro-morphological status, pollution, hydropeaking);
- Using the results (e.g., pressures on freshwater and wetland related habitats) to develop scoring criteria which can be projected in geographic space with collected geo-datasets.

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2.7. Annex

Past meetings

Events contributed within the frames of the ICPDR, CC and EUSDR

- 16.02.2023: WWF-CEE, BOKU, ICPDR, CC planning meeting, Vienna, Austria
- 22.03.2023: ICPDR HYMO Task Force Meeting ICPDR (BOKU)
- 27.04.2023: ICPDR RBM Meeting (BOKU)
- 16.05.2023: 9th WG on Sustainable Forestry Meeting, online (CC, WWF-CEE)
- 22.-24.05.2023: 14th WG on Biodiversity Meeting, Vsetín, Czech Republic (WWF-CEE, WWF-RO, IIASA)
- 27.09.2023: ICPDR HYMO Task Force Meeting, online (BOKU, WWF-HU)
- 11.-13.10.2023: Stakeholders' Consultation at the 7th Conference of the Parties to the CC, Belgrade, Serbia (WWF-CEE, WWF-RO, IIASA)
- 19.-20.10.2023: ICPDR RBM Meeting (BOKU, WWF-HU)
- 6.-7.11.2023: EUSDR Priority Area 6 on Biodiversity Meeting, Kopačky Rit, Croatia (WWF-HU)
- 23.11.2023: SCC & WWF-CEE planning, Vienna
- 12.-13.12.2023: ICPDR Ordinary Meeting, Vienna, Austria (BOKU, WWF-CEE, WWF-HU)
- 17.01.2024: SCC & WWF-CEE planning, online
- 06.03.2024: ICPDR HYMO Task Force Meeting, Munich, Germany (BOKU, WWF-HU)
- 21.03.2024: SCC & WWF-CEE planning, online
- 22.04.2024: SCC & WWF-CEE planning, online

Presentation of the case study at multiple events

- 06.02.2023: IAD conference, Krems, Austria (BOKU)
- 20.-24.08.2023: AFS Conference, Grand Rapids, Michigan, USA (BOKU)
- 25.09.2023: BOKU Data Science Initiative "Spatiotemporal Analysis", Vienna, Austria (BOKU)
- 22.-24.11.2023: BOKU Biodiversity Days, Vienna, Austria (BOKU)

Future meetings

Future meetings in the frame of the Carpathian Convention, ICPDR and EUSDR platforms

- ICPDR: attendance of HYMO and RBM meetings (twice a year, if relevant updates need to be communicated of feedback/input is required);
- CC: attendance of WGs on Biodiversity, Forestry, Climate Change meetings, organising cross-sectoral meetings and workshops for co-creation of TEN-N, capacity building and funding opportunities, joining the Carpathian Convention Implementation Committee Meetings, all organised once a year;

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- EUSDR: attendance of PA4, PA5 and PA6 Meetings if relevant, EUSDR Annual Forum depending on the topics.

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3. Finland case study

Authors

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3.1. Identification of conservation planning challenges

Finland is the northernmost member state of the European Union. Together with Sweden, it hosts most of EU's boreal and sub-arctic ecosystems. The country is home to several iconic and threatened boreal and sub-arctic species, such as the Siberian flying squirrel, the white-backed woodpecker and the arctic fox, and boasts some of Europe's last remaining populations of large carnivores (brown bear, wolf, European lynx and wolverine). Dotted with lakes and mires, the natural habitats range from the sandy and rocky shores of the unique Baltic Sea to the open sub-arctic mountains of the north. Approximately 75% of Finland's land-area is covered by forests, constituting a notable carbon sink within the EU.

The primary driver of biodiversity decline in Finland is the degradation and loss of natural habitats. Finland's forested landscape has been heavily modified by industrial forestry, as nearly 90% of the forested area is in economic use. Currently, approximately 13% of Finland's terrestrial area and inland waters, and 12% of its marine areas, are protected, most of these falling under strict protection. However, the national protected area network is heavily biased towards the less populated and less productive sub-arctic fell and mire habitats of Northern Finland (Fig. 1). Thus, many of the boreal and hemi-boreal habitats of Central and Southern Finland have a low coverage of protectiveness and the areas that are protected tend to be smaller and less well-connected, decreasing the likelihood that protected area network can buffer biodiversity from additional pressures.

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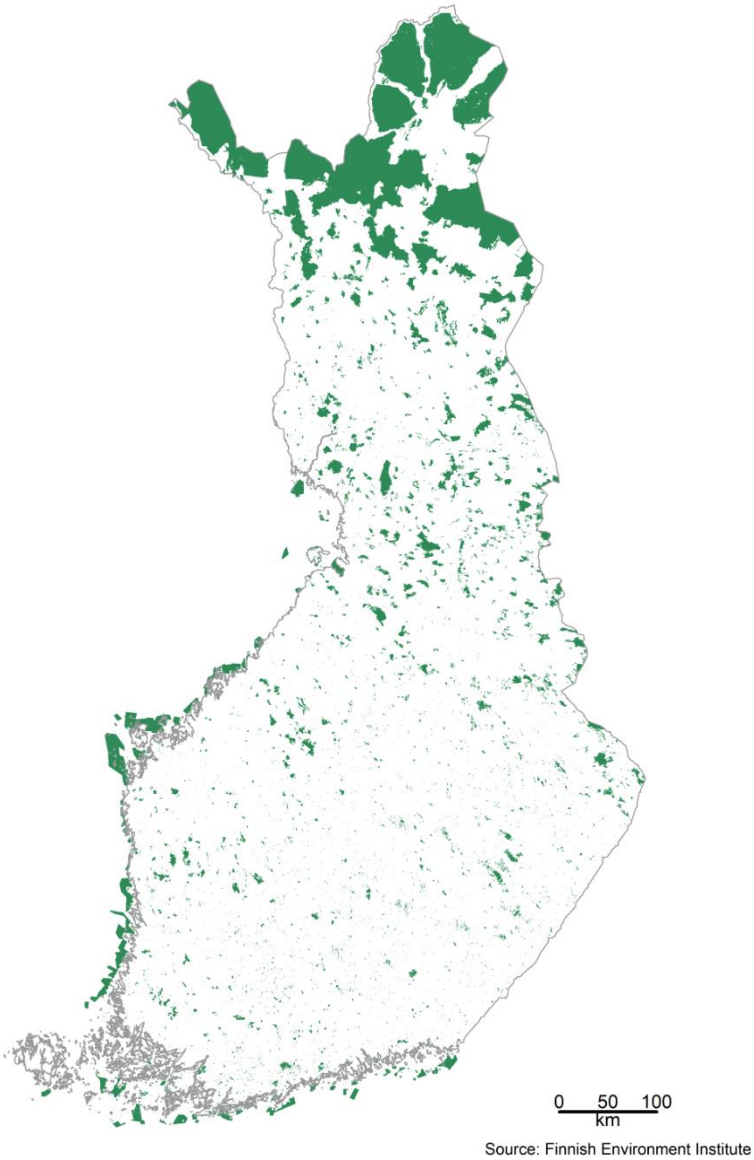

Figure 1. Currently protected terrestrial and marine areas in Finland. The large areas in Northern Finland include 12 near natural state areas protected by the Wilderness Act where traditional means of livelihood, such as hunting, fishing and reindeer husbandry, can be practiced, subjecting them potentially to a wider range of human activities than the areas under Conservation Act.

A major challenge in increasing the coverage of protected area network is that most of the remaining high-quality, non-protected habitats in Central and Southern Finland are located on privately owned lands. This calls for a diverse portfolio of mechanisms, including diverse funding mechanisms, to increase the coverage of protected areas in Finland.

Due to its location in the boreal and sub-arctic region, Finland also hosts many biotopes and species that are likely to be negatively impacted by climate change and are thus at risk of regional extinction within the EU. In addition, large parts of Northern Finland are home to Europe’s only indigenous group, the Sámi, whose traditional livelihood (reindeer herding) and connection to the land constitute a central aspect to all land use and management plans in the region.

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3.2. Case study objectives

Through the case study of Finland, NaturaConnect provides data and supports to the national preparative process of the pledge. This will include provision of biodiversity data which has the potential to support the identification of the important areas for the pledge, as well as future scenarios of the anticipated impacts of climate change and land use. Another overarching aim is to provide feedback on the targets, data and scenarios produced in NaturaConnect and to compare these data and results to those at the national level. The case study will explore the differences in biodiversity targets, conservation and connectivity needs that arise at national versus EU level planning. This comparison seeks to understand where the national pledge could be refined and what additional opportunities may arise for implementation, e.g., for enhancing Europe-wide connectivity. The project also provides an opportunity to identify and – where feasible – resolve potential conflicts between national and EU-level priorities early on and to explore the options of financial instruments towards the realization of the national network.

3.3. Stakeholder engagement

The work of the Finnish case study is intimately linked both with the governmental work and conservation research that are at the core of the country's efforts to prepare its pledge for the EU Biodiversity Strategy targets. Through this case study, NaturaConnect plays a pivotal evaluative role in the pledge preparation process and its qualitative assessment by providing biodiversity and other data to support the identification of key biodiversity areas. The key stakeholders to which the case study has established operable and permanent relationships to support the pledge development process include the Ministry of the Environment (MoE), Metsähallitus Luontopalvelut (Parks and Wildlife Finland), Natural Resources Institute Finland (LUKE), and a number of relevant research and expert projects at Finnish Environment Institute. These projects, described in detail in Task 1, are mainly commissioned by the MoE and are directly linked to the pledge development or addressing the national or EU level conservation questions that are closely related to the EU Biodiversity Strategy targets.

3.4. Policy context and financial mechanisms

The designation of different types of protected area in Finland is largely based on the Nature Conservation Act, initially established in 1923, and renewed in 1996 and 2023. The Nature Conservation Act, after the renewal in 2023, includes currently also aspects of connectivity (operationalized, for example, via water courses) and new grants to support nature conservation.

The Nature Conservation Act includes a set of national definitions approved by the Parliament of Finland for different types of nature conservation areas, as well as habitats, landscapes, and species of conservation concern. These provide guidelines and rules for the selection criteria, spatial planning, establishment process and code of conduct for the different protected area types. The code of conduct varies between different protected areas, being most restrictive in the Strict Nature Reserves where human activity is strongly prohibited. Hunting and recreational fishing is allowed in most protected areas, but hunting is regulated through hunting rights and permits. Finland executes the freedom to roam, or everyone's right, which allows people to freely access all areas where it does not harm the environment or landowner's rights, including privately owned lands. Within it, people have the right to camp for short term and to pick berries and mushrooms, but they are not allowed to harm animals or plants or to

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cut woody plants e.g., for firewood. Of protected areas, only the Strict Nature Reserves fall outside everyone's right.

The largest of the different types of protected areas established by the Nature Conservation Act in Finland are the two types of Nature Parks, i.e., National Parks and Strict Nature Reserves. Generally medium- or small-sized protected areas have been established to protect the most valuable representations of certain ecosystems and habitats with high or unique biodiversity values; these include old-growth forest reserves, mire conservation reserves, and herb-rich forest reserves. Additional types of state-governed protected areas include the Protected Forests that are protected based on decision by Metsähallitus (a state-owned enterprise governing public lands in Finland), the protected areas designated in land use plans, based on Regional Council decision, including the Sites of Community Importance and Special Areas of Conservation (Habitats Directive) and the Special Protection Area (Birds Directive), as well as occurrences of nationally designated Protected Habitat Types. The designation principles for these protected areas were to some degree based on systematic conservation planning approaches, utilising scientific analysis and criteria, that would best serve the conservation aims. As regards their funding, these areas were established on state-owned land or on land purchased by the state.

In Northern Finland the Nature Conservation Act is complemented by the Wilderness Act which has been the basis to delimit and designate large areas as Wilderness Areas. The key aims of establishing Wilderness Areas are to preserve unique landscapes and the nature characters that they include, secure the Sámi culture, and sustain their traditional land uses and livelihoods. Thus, Wilderness Areas are, by definition, less restrictive to human activities than many of the areas protected by the Nature Conservation Act. Some level of protection of nature is provided also by the National Hiking Areas, founded based on the Outdoor Recreation Act (1973), which include certain aspects comparable to protected areas and correspond either to IUCN category II or V.

In addition to the state-funded types of protected areas, there are also privately-owned conservation areas. These are generally small sized, and their establishment is based on the voluntary will of private landowners to protect valuable land. The government compensates the landowner with a lump sum that corresponds to the economic losses corresponding to opportunity costs of timber sales.

Most of the areas included in the Finnish protected area network are also designated as Natura 2000 protected areas. The overall coverage of the Natura 2000 network is 12.6% of land territory in Finland. Within this network, there are special protection areas (SPAs) classified under the Birds Directive covering 7.3% and Sites of Community Importance (SCIs) under the Habitats Directive covering 12.5% of the country's territory. In comparison, the total terrestrial protected area covers 13.3% of land area.

The current financial mechanisms for nature protection in Finland include a notable element of public funding, channelled via earlier conservation programs and the more recently launched programs METSO and HELMI. Earlier conservation programs, led by the Ministry of the Environment, targeted specific natural habitats (e.g., old-growth forest, wetland, mire, herb-rich forest conservation programs, respectively) with set area targets per program. Although these programs have already mostly finished, small number of areas are still being designated through them each year. Through the METSO program (I in 2002, II during 2008-2016), private landowners can, voluntarily, offer their forests with high biodiversity values for permanent or fix-term protection. More precisely, the METSO programme funds biodiversity conservation in commercially managed forests by means of permanent protection or, alternatively, fixed-term environmental forestry subsidy agreements and nature management projects, encouraging private owners to protect their forests temporary or via everlasting conservation management agreement. In exchange, they receive full financial compensation equivalent to the value of timber. The areas accepted to the METSO program may thus either remain under the ownership of the landowner, being protected using a fixed-term contract (10-

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30 years) or permanently, the latter forming a Private Nature Reserve, or it can be purchased by the state, making it a state-owned protected area. The program includes several measures to improve ecological connectivity, such as the establishment of ecological networks.

The HELMI program was launched in 2019 to complement the METSO program. It aims to increase the conservation and restoration of open (non-forest) habitats, including mires, wetlands, small water bodies and shore habitats, and semi-natural grasslands. Both the METSO and HELMI programs function on a voluntary basis and are jointly run by the Ministry of Agriculture and Forestry and the Ministry of the Environment.

The current network of protected areas in Finland forms the basis for the national pledge definition process. In 2022, according to the nationally designated area database (CDDA) 13.3% of Finland's terrestrial and freshwater area and 10.9% of the marine areas were covered by either protected areas or Natura 2000 areas. Similarly, 10.5% of terrestrial and freshwater and 4.5% of marine areas were considered strictly protected and these will form the basis of strictly protected area coverage for Finland's pledge. These areas include the large northern Wilderness areas. Noteworthy for this process is that the definition of areas to be considered as OECM areas is currently pending and under preparatory work by public servants in the ministry. The first assessment aims to identify area categories that could be suggested as OECMs, the designation of sites for expanding protected areas, and defining criteria for and what activities can be allowed within them. This assessment is carried out by experts in the Finnish Environment Institute. Based on this the Ministry of the Environment will compile the national pledge to be submitted to the European Commission within 2024. Overall, the drafting of the national pledge in Finland is led and coordinated by the Finnish Ministry of the Environment (MoE) in close collaboration with the Ministry of Agriculture and Forestry (MoAF). The initial scoping of the national pledge development process was carried out in 2022 by a cross-sectoral Working Group including stakeholders from industries, land ownership groups, NGOs (including conservation), and civil societies. Since the start of 2023, the drafting has continued within the MoE.

3.5. Methodological approaches and preliminary results

Below, we describe the different tasks in the order of priority and chronology, i.e., the order in which they will be commenced. The final details, and potential to implement overall, of the task including quantitative analysis (Tasks 2 to 5) will depend on the process with the stakeholders and projects (including other NaturaConnect WPs) whose outputs we are dependent on. Thus, there is a relatively high probability of changes to the plans described below and not all quantitative tasks will necessarily be conducted within the scope of NaturaConnect.

3.5.1. Task 1 - Stakeholder engagement and coordination of information flow

Objective

Active stakeholder engagement is key to gain timely information on and the opportunity to engage with the national pledge preparation. This allows the case study to introduce data and results from the project to key stakeholders as well as gather feedback on these. The aim of this task was to establish regular dialogue with the Finnish Ministry of the Environment (MoE) and other relevant projects that influence the pledge process, which were identified as key stakeholders in the initial stakeholder mapping (Table 1). The meetings between the case study, MoE and associated projects focus on pledge preparation, discussing data gaps, and identifying information and analysis needs.

Table 1. Results of initial stakeholder mapping. The table lists potential stakeholders to NaturaConnect in Finland, reviewed from the perspective of the case study and assessed in terms of their

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interest/engagement towards the project and influence/power on the national pledge. Key stakeholders are highlighted. The initial term of the cross-sectoral National Working Group came to an end at the start of NaturaConnect project (Dec 2022), and currently the preparation is being led by the Finnish Ministry of the Environment.

Stakeholders	Interest / Engagement	Influence / Power
National Administration		
Finnish Ministry of the Environment	4	5
Finnish Ministry of Forestry and Agriculture	4	3.5
Ministry of Finance Finland	1	3.5
Metsähallitus Forestry Ltd	3	4
Metsähallitus Parks and Wildlife	4	3
National Working Group preparing the Finnish pledge	5	5
Steering group of the Finnish pledge WG	3	4
Regional Administration		
Regional Centres for Development, Transport and the Environment (ELY)	4	4
Regional State Administrative Agencies (AVI)	2	3.5
Regional forest centres	3	2
Academia / Research centres		
Commissioned projects providing data into pledge preparation	5	4
Research Institutes (SYKE, LUKE, EFI (European Forest Institute), universities)	3	2
Luontopaneeli (Finnish IPBES)	4	3.5
Ilmastopaneeli (Finnish IPCC)	2	2.5
Other relevant research projects	4	2
Private sector		
Forest industry	3	4
Energy sector	2	2
Mining industry	2	2
Tapio (provider of forest management related advisory and consulting services)	3	2
Other relevant consultancies (forestry and environment)	2	1
NGOs		
SLL, WWF, BirdLife Finland, etc.	4	3
MTK	4	4
Hunters Association	1	1.5

Methods

Our main mode of operation is the regular and active engagement with key stakeholders. In addition, we facilitate bilateral information flow between the NaturaConnect project and the national pledge preparation. This has been realized through following activities:

- biannual meetings with MoE;
- bimonthly meetings with MoE commissioned projects;
- attendance in national stakeholder meetings;

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- attendance in workshops and seminars relevant to the pledge preparation.

Regular meetings with associated commissioned research projects ensure an effective flow of information on the pledge preparation process as well as nationally important areas for the EU Biodiversity Strategy. All these projects are MoE commissioned and conducted by experts at the Finnish Environment Institute (Syke; projects described in more detail below). In essence, these projects focus on data and information gathering regarding the ecological status and extent of current protected areas in Finland, assessment of trends and management of directive species and habitats, potential OECM areas and the national definitions of old-growth and pristine forests, providing central information for the EU level and national conservation priorities.

A summary of the MoE commissioned associated projects led by Syke, which support the preparation of the Finnish pledges

The project **“Towards coherent protected area network in Finland” (KOKASU)** collects key literature-based and spatial biodiversity information to support national definition and implementation of the targets of the EU Biodiversity Strategy to protect a minimum of 30% of the land area and 30% of the sea area to improve connectivity and coherence of the protected area (PA) network. Overall aim of the project is to determine thematic and regional gaps and main deficiencies in present-day biodiversity conservation and PA network in Finland for eight main habitats: Baltic Sea, coastal habitats, fell habitats, forests, inland waters and shores, mires, rocky habitats and seminatural grasslands. Particular attention is paid to assessing the potential for new protected areas for the threatened habitat types and species at risk.

The project **“Coordination of the EU Biodiversity Strategy’s restoration targets” (EUKUKO)** provides expert-based support to Ministry of environment and the working group assigned for the preparation of the biodiversity pledges of Finland for the EU Biodiversity Strategy, in particular with regards the determination of aims and measures to implement restoring activities for degraded ecosystems, habitats and species across the EU’s land and sea areas in order to enhance the recovery of biodiverse and the resilience of nature. A focal theme is to advance the implementation of the pledges as well as monitor and evaluate the targets and progress in the restoration and improvement of habitats in the projects related to EU Habitat and Bird Directives.

Using an extensive and versatile spatial data on different factors affecting forest biodiversity, the project **MetZo III (“Decision support for ecologically based planning”)** develops nation-wide and regional ecological prioritisation analysis and information to support decision making in environmental governance and policies at different levels. Results of the project support developing or expanding nature conservation network as well as the spatial planning for more sustainable land use. In the core of the ecological decision-making assessments by the project are Zonation-based analyses conducted for and used in METSO - The Forest Biodiversity Programme for Southern Finland that aims to bend the declining trends in the forest biodiversity into stable or favourable trends by 2025.

“The Other Effective Conservation Measures (OECM) – evaluation of available datasets and developing the reporting as part of the implementation of the commitments of the EU BD Strategy”, a joint project between the Finnish Environment Institute (SYKE) and Natural Resources Institute Finland (Luke), is designed to enhance the implementation of national pledges to achieve the target of conserving 30% of natural areas by the year 2030. The project's objectives include establishing a framework for organizational roles in identifying and reporting potential OECM areas, compiling and reporting qualifying areas to the database of protected areas in Europe (Common Database of Designated Areas CDDA) and compile a proposal on measures and data supplements for areas that do not yet meet the OECM criteria. The project will prepare a data management plan for the reporting process and practices and pilot the data management and reporting processes for areas that meet the criteria.

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Syke is also the national focal point for **assessing, monitoring and reporting of the conservation status of species and habitat types included in the Birds and Habitats Directives**, the two cornerstones of EU biodiversity policy. SYKE coordinates the regular assessments and reporting of the conservation status of species and habitat types to the Commission where the key applied criteria are status and changes in the range, distribution area, habitat conditions, state of populations, and the environment which the species inhabit, as well as the foreseen future trend in the conservation status. The information gathered in assessments are employed, e.g., in developing conservation and management plans to ensure reaching and maintaining the favourable conservation status of the species and habitat types that are present in the country and that are covered by the Birds and Habitats Directive species, also in the long-term.

Results and short conclusions

During the first reporting period, the case study arranged regular meetings with the Finnish MoE. Moreover, the case study has participated in a number of events to meet stakeholders, including the national stakeholder meetings organised by the MoE (June and September 2023, to discuss and provide feedback on the draft of the national pledge), and the Boreal Biogeographical seminar (October 2023, allowing the exchange of knowledge, data, and experience between Boreal region countries, as well as gathering feedback for NaturaConnect findings). In addition, the case study has promoted the NaturaConnect project by establishing links between other WPs and relevant local stakeholders, including a provision of direct feedback route to NaturaConnect work design and outputs (e.g., D1.1., D4.1. and D5.2).

In autumn 2023, as the first drafts of the pledge became available to stakeholders, the case study worked together with the MoE to co-design exact analysis options for the work to be carried out by the case study. The case study has also generated a link between NaturaConnect and the Strategic Research Council-funded MUST (“Enabling multispecies transitions of cities and regions”) project (Fig. 2). This collaboration will allow developing regional analysis of ecological connectivity of PA network in Finland, thereby providing a comparison point to EU level connectivity assessments.

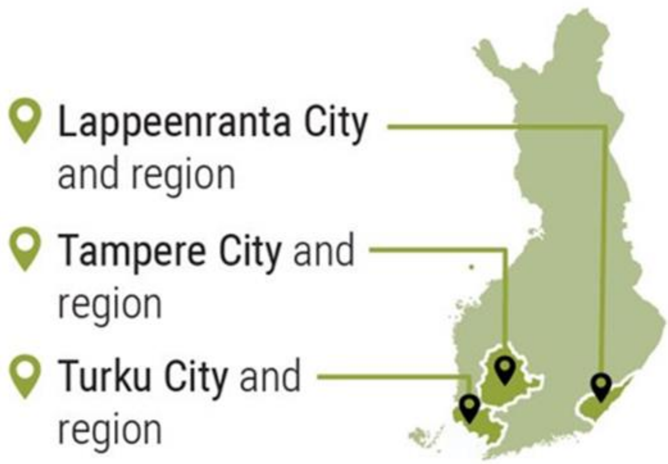

Figure 2. The focal regions of the “Enabling multispecies transitions of cities and regions (MUST)” project funded by the Strategic Research Council of Finland.

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3.5.2. Task 2 - Connectivity analyses

Objective

In this task, we will perform ecological connectivity analyses and scale/spatial extent comparisons by, where possible and recommendable, examining both structural and functional connectivity. The structural analysis focuses on the distribution and connectivity of habitat patches including selected quality features that are considered to support biodiversity. In contrast, functional assessments are based on, for example, 'resistance to movement' spatial data layers, occurrence patterns of indicator species of focal habitats and/or archetype species, using graph theory -based methods, least-cost path or circuit theory –based methods (Circuitscape, Omniscape) applied across the whole forested land of Finland (national scale) and in three focal regions in southern Finland (Southwest Finland, Pirkanmaa, and South Karelia, produced via the collaboration with the Strategic Research Council-funded project MUST). We will evaluate method integrity and scalability by comparing 1) regional results (produced by MUST) to 2) a nationwide ecological connectivity outputs (to be produced as part of NaturaConnect Task 2) and areas determined as crucial to connectivity therein and 3) pan-European outputs from the NaturaConnect project (produced by NaturaConnect WP6).

Data and methods

The analysis will use spatial data, e.g., on biodiversity (focal habitats, species distributions - produced by NaturaConnect WP3 -, traits) and infrastructure (species mobility networks, movement resistance layers, including both generic obstructing land use as well as species-specific resistance layers, protected area network). In extended analysis, complementary data on geodiversity (topography, soil), climate (temperature, snow), and where applicable, future scenarios (climate change, forestry) will also be used. Where data on real-life species is limited, archetype species (produced by NaturaConnect WP6 and the project MUST) will be constructed based on a variety of ecological parameters (hypothesized archetype species based on combinations of parameters like dispersal ability, habitat use, longevity). The regional and national analyses may be complemented with relevant national or regional datasets. Sensitivity analyses will be carried out across a range of parameters and archetype species.

Results and short conclusions

Through the analysis results we will be able to identify critical habitat patches and functional corridors that maximize requirements for different types of species groups for a variety of scaling choices while avoiding conflicts and resistance in relation to diverse values of society. This will support the aims of the NaturaConnect WP8 to pinpoint the potential conflicts between national and EU-level priorities and identify which areas contain the highest amount of uncertainty pertaining from a) species type, b) scaling choice, c) future scenarios.

3.5.3. Task 3 - National level analysis of the NaturaConnect opportunity cost data

Objective

One of the key objectives of the NaturaConnect case studies is to provide national and local level feedback to the data and results produced in the project. In this task we focus on one of these outputs, the European wide opportunity costs' estimates (produced by NaturaConnect WP4; D4.1) for pastures. This will allow us to explore options for refinements, with a particular emphasis on the Finnish and Boreal region context.

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The NaturaConnect opportunity cost estimates for Europe approximate the monetary values of conservation-based opportunity costs, i.e., the foregone economic benefits of exploitation when setting aside land for nature conservation or restoration. The opportunity cost delivered by WP4 are based on land rent, i.e., the total net revenue or benefits from a parcel of land. For production land (arable, pastoral and forestry land), regional and national land rent data were allocated to the planning units (grid cells) based on the yields of crops, livestock products and wood combined with country-specific commodity prices. For urban land, empirical data on property rents for a sample of cities was extrapolated across countries based on settlement density, assuming a linear relationship between property rents and density of housing.

In this task, we focus specifically on one aspect of the opportunity cost of production lands, that is pastures (Fig. 3). In the first version of the NaturaConnect opportunity cost estimates for pastureland were based on the density of livestock, specifically of the number of goats, sheep and cattle per ha, respectively, extracted from the Gridded Livestock of the World (GLW4) database (Gilbert et al., 2022a, 2022c, 2022b). This data does not include information on the number of reindeer, which is the primary livestock in the most northern parts of Nordic Member States. Reindeer husbandry is also a central form of the livelihood and cultural heritage of Europe's only indigenous group, the Sámi. Excluding reindeer husbandry from the opportunity cost estimates explicitly excludes the most central economic costs of conservation that are incurred to the Sámi people in these regions if reindeers are not allowed to move freely and graze in the newly protected areas.

The objective of this task is to search and prepare data that could be used to refine the first version of opportunity cost estimates, to better capture the aspect of reindeer husbandry.

Data and methods

Opportunity cost layer for pastoral land (D4.1):

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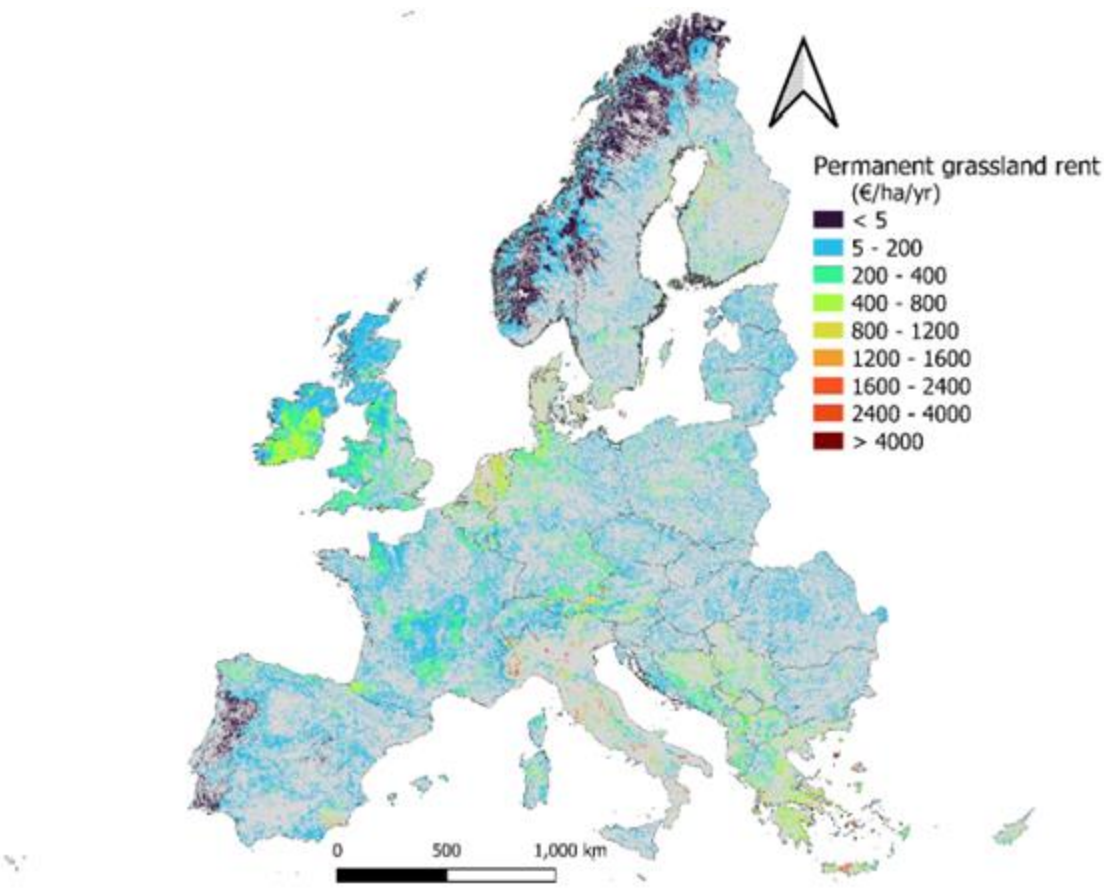

Figure 3. Opportunity cost layer for pastoral land in Europe in € /ha/yr (from D4.1).

Reindeer density data from Finland:

- Original density data is available from the Open Information service Liiteri (https://liiteri.ymparisto.fi/);
- Maximum number of allowed live reindeer for each reindeer herding community (in Finnish: "Paliskunnan alueella pidettävien eloporojen suurin sallittu määrä") is provided for 2021, which is the latest statistic ("Eloporoilla tarkoitetaan paliskunnan erotuksissa eloon luettuja ja elämään jätettyjä poroja, eli talven yli eläneitä poroja" – The max number is based on the animals that are left alive after autumn slaughter);
- The density data can be combined with spatial polygon data delineating the areas of different reindeer herding cooperatives, provided by the Reindeer Herders' Association in Finland;
- Then from these, the maximum density (number of animals per ha) allowed for each cooperative (Fig. 4) can be established.

The Reindeer husbandry area in Finland is divided into 54 different cooperatives. Reindeer herding cooperatives vary in the size of their total area and number of reindeer. Every cooperative is responsible for the reindeer herding in its area. Cooperative is a community formed by the reindeer herders and every herder can belong to one cooperative.

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The maximum number of animals allowed within the total Reindeer husbandry area and within each cooperate is set by the Finnish Ministry of Forestry and Agriculture for each 10-year period (current period 2020-2030). With this cap, the Ministry aims to control the risks of overgrazing caused by the freely roaming reindeer.

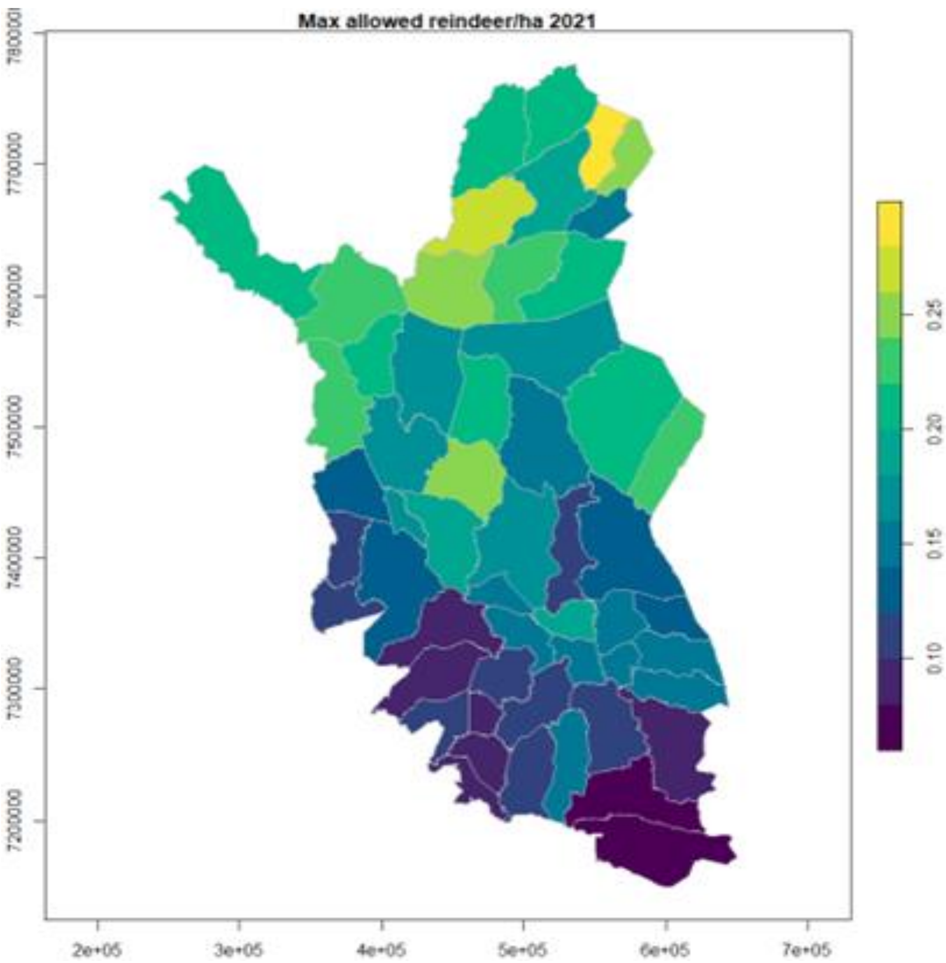

Figure 4. Maximum allowed reindeer density (animals/ha) for 2021 for each reindeer herding cooperative in Northern Finland.

Results and short conclusions

For most parts, reindeers are allowed inside PAs in Finland, except for strict nature reserves. Hence, establishing new protected areas in the reindeer husbandry area does not necessarily incur opportunity cost to reindeer herding unless grazing is explicitly banned from these areas. This will depend on how strict protection will eventually be defined by the EU and by Finland. Currently, the Finnish government will likely include all types of protected areas within the strict category of protected areas in the pledge, also those where reindeer herding is allowed. If this allocation is not accepted by EU, the density of reindeers could be included in the opportunity cost layer for strict protection and thereby allow a more informed and realistic opportunity cost estimate compared to D4.1.

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3.5.4. Task 4 - Comparison of network design and efficiency when planning is done at different scales

Objective

According to the EU Biodiversity Strategy, the area targets of 30% protection and 10% strict protection need to be achieved across EU and within each major biogeographical region. However, the Finnish government will likely base the national pledge on an allocation of new protected areas that does not account for existing differences in the PA network coverage between the two terrestrial biogeographical regions in Finland (boreal and alpine, Fig. 5b). Since the largest extent of existing PAs are situated in the north of Finland (Fig. 1), and thus in the alpine region, this will in practice lead to a lower apparent need of expanding PAs in the south of Finland (boreal region, Table 2). To showcase the differences such a political choice entails for protecting biodiversity across the different biogeographical regions in Finland, we will analyse the need and identify priority locations for new protected areas that, together with existing protected areas, reach 30% protection of terrestrial area either 1) both the boreal and alpine regions separately, and 2) the boreal and alpine regions combined. Depending on negotiations with the case study stakeholders, we might also evaluate additional strategies, such as the proposal of the Finnish Nature Panel to achieve the area targets within each administrative region (Fig. 5a, Kotiaho et al. 2021) or at finer biogeographical scale (Fig. 5b). We will also estimate the biodiversity outcomes of the different approaches for developing the national protected area network.

Table 2. Current coverage of strictly protected areas in Finland as reported in the nationally designated Protected Areas database (CDDA) in 2022 and updated status in September 2023. The coverage has been broken down to each biogeographical region, the combined terrestrial regions and for the entire country. These areas will be counted towards the 10% target of strict protection.

Biogeographical region	Protected (ha) 2022	Coverage (%) 2022	Coverage in September 2023
Baltic Sea	338 120	4.1	4.5
Boreal	2 356 030	7.3	7.5
Alpine	1 203 260	73.6	73.6
Terrestrial combined = Boreal + Alpine	3 559 290	10.5	10.7
Country total	3 897 410	9.3	9.5

Data and methods

The analysis will utilize nationally available biodiversity data collected in Task 5 and spatial data on current protected areas in Finland (Fig. 1). Priority areas for additional protection will be identified using the spatial prioritization software Zonation v. 5.1 (Moilanen et al. 2022). Areas needed to achieve the 10 and 30% targets will be identified using different conservation strategies: achieving the targets within 1) the combined area of alpine and boreal regions (current policy); 2) for alpine and boreal regions separately (EU Biodiversity Strategy policy); 3) (not confirmed) for each administrative region of Finland (Fig. 5a) or for finer biogeographical region (Fig. 5b). Other areal strategies may also be considered. We will summarize the biodiversity outcome by reporting how well biodiversity features protection will be increased in each strategy.

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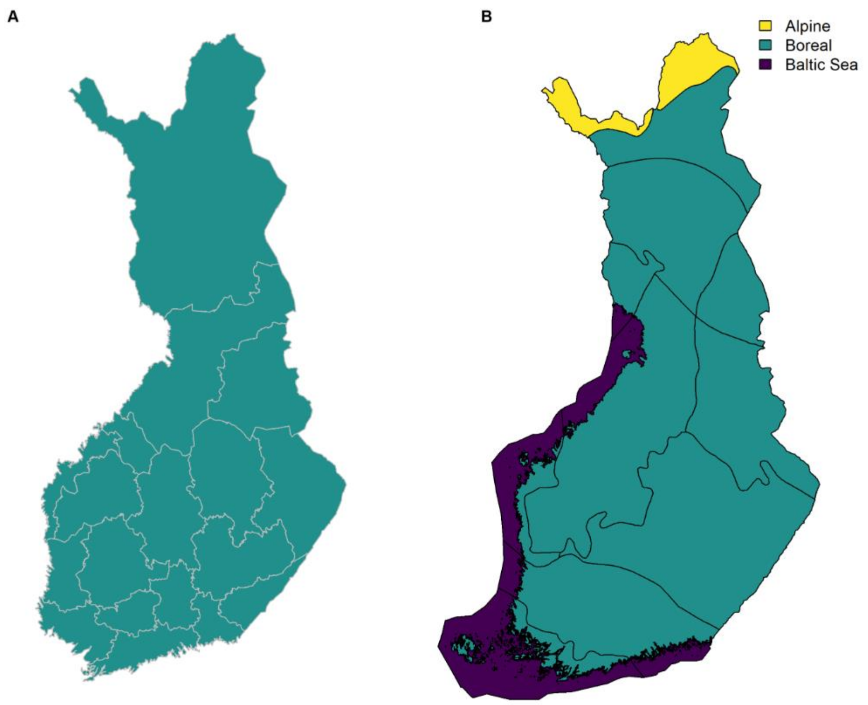

Figure 5. Different potential scales for the analysis. A: Administrative regions of Finland, excluding the autonomous region of Åland Islands. B: Biogeographical regions (alpine, boreal, Baltic Sea) as defined for the EU Biodiversity Strategy pledge preparation, shown in different colours. The black lines give the national, finer division of biogeographical regions in Finland.

Results and short conclusions

To be announced.

3.5.5. Task 5 - Comparison of national conservation priorities and TEN-N solutions

Objective

Conservation priorities depend on the data, scale and context used to define them. While EU-wide prioritisations have the advantage of improved cost-efficiency (Kukkala et al. 2016) and the ability to consider cross-border connectivity needs, national assessments are often based on more detailed information on the spatial distribution of biodiversity values and relevant land use constraints.

In this task, we will analyse the differences that emerge between the TEN-N solutions produced by NaturaConnect and the priorities identified in national analyses in Finland. By necessity, the two solutions are likely to differ as they are based on different objectives, data and optimisation method. In NaturaConnect, priorities are identified using predominantly modelled data on the distribution of species and habitats and the optimisation is target-based, meaning that the priority areas are selected so that set coverage (area) targets can be achieved for as many species and habitats as possible. The national prioritisations are more commonly based on finer resolution observed or remote sensed data, lean more heavily on habitat types than individual species and utilise detailed information on the ecological condition of candidate sites (e.g., Mikkonen et al. 2023). In addition, the national priorities are typically

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identified using a maximum-utility type of optimisation, where the amount of habitat covered is maximised for each additional area protected, without setting hard species or habitat specific targets. Another major difference between the two approaches is that TEN-N solutions produced by NaturaConnect will consider future changes in biodiversity patterns, as driven by climate and land use change, as well as cross-border connectivity needs, which cannot be assessed at the national scale.

Despite the evident methodological differences, the focus of this task is not in comparing the approaches *per se* but rather to understand 1) what additional information does the EU-wide analysis provide that could be utilised in the development of the national protected area network in Finland, and 2) how the TEN-N solutions can be improved based on the insights that emerge from the comparison.

Data and methods

The TEN-N solutions will be produced by WP7. They will be based on the distributions of species, habitats and ecosystem services produced by WPs 3 and 4, and the climate and land use scenarios produced by WP5. Connectivity needs will be analysed by WP6 and incorporated in the final TEN-N solution. The final product will display, at 1x1km resolution, the proportion of each spatial unit (grid cell) that should be protected in order to achieve the 10% and 30% area target while also maximising the number of species and habitats that meet a set conservation target, based on the species and habitat specific FRVs calculated in T7.1.

Based on current knowledge, the national pledge process in Finland will not include a spatial identification of pledged areas. The data for national priorities will therefore be based on a set of previously conducted analyses which are likely to form the basis of designating some of the new protected areas in the future (Table 3). These analyses utilise various Finnish datasets at high resolution on biodiversity and the ecological condition of each site. In addition, Finland is currently in the process of finalising the national criteria to identify its remaining primary and old-growth forests. Based on these criteria, all remaining primary, old-growth forest on state-owned land will be protected. On privately owned lands, protection of primary and old-growth forests will be voluntary. Once decisions around additional protection of primary and old-growth forests on state-owned lands are finalised, we will incorporate the associated spatial data to this analysis.

The national priorities will be either directly compared with the TEN-N solutions produced by NaturaConnect, or the underlying input data will be harmonised and merged to a new prioritisation.

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Table 3. Data sources for national priorities. Note that this is not a final list of potential datasets but will be updated during the course of the project.

Source	Type of habitat	Resolution	Description
Mikkonen et al. 2023	Forested areas	96x96m	Priority areas for forest conservation. Based on observations of red-listed forest species and forest structures known to indicate valuable forest for biodiversity (dead wood potential, Mikkonen et al. 2020), estimated from remote-sensed data for 20 forest types (combinations of main tree species and siter fertility).
Kujala et al. In prep Forsius et al. 2023	Forested areas	96x96m	Priority areas for preserving forest biodiversity and carbon. Biodiversity as in Mikkonen et al. 2023 + spatial data on concentration of old-growth forests (pine, spruce and deciduous dominated, respectively) and modelled distributions of 6 forest indicator species (goshawk, common buzzard, European honey-buzzard, white-backed woodpecker, three-toed woodpecker and lesser-spotted woodpecker, Virkkala et al. 2022). Size of potential carbon storage and sink at each forest site estimated based on process model PREBAS (Minunno et al. 2019)
Kareksela et al. 2020	Mires	50x50m	Priority areas for mire conservation. Based on a comprehensive field survey of the candidate sites, a pre-existing and highly detailed habitat database on protected areas, small water bodies from topographic databases, modelled likelihood for mire bird species territories, and observations of threatened mire species
TBA	Primary and old-growth forests	TBA	Remaining primary, old-growth forests on state-owned lands that meet the nationally set criteria and will be protected as part of Finland's pledge towards the EU Biodiversity Strategy targets.

Results and short conclusions

To be announced.

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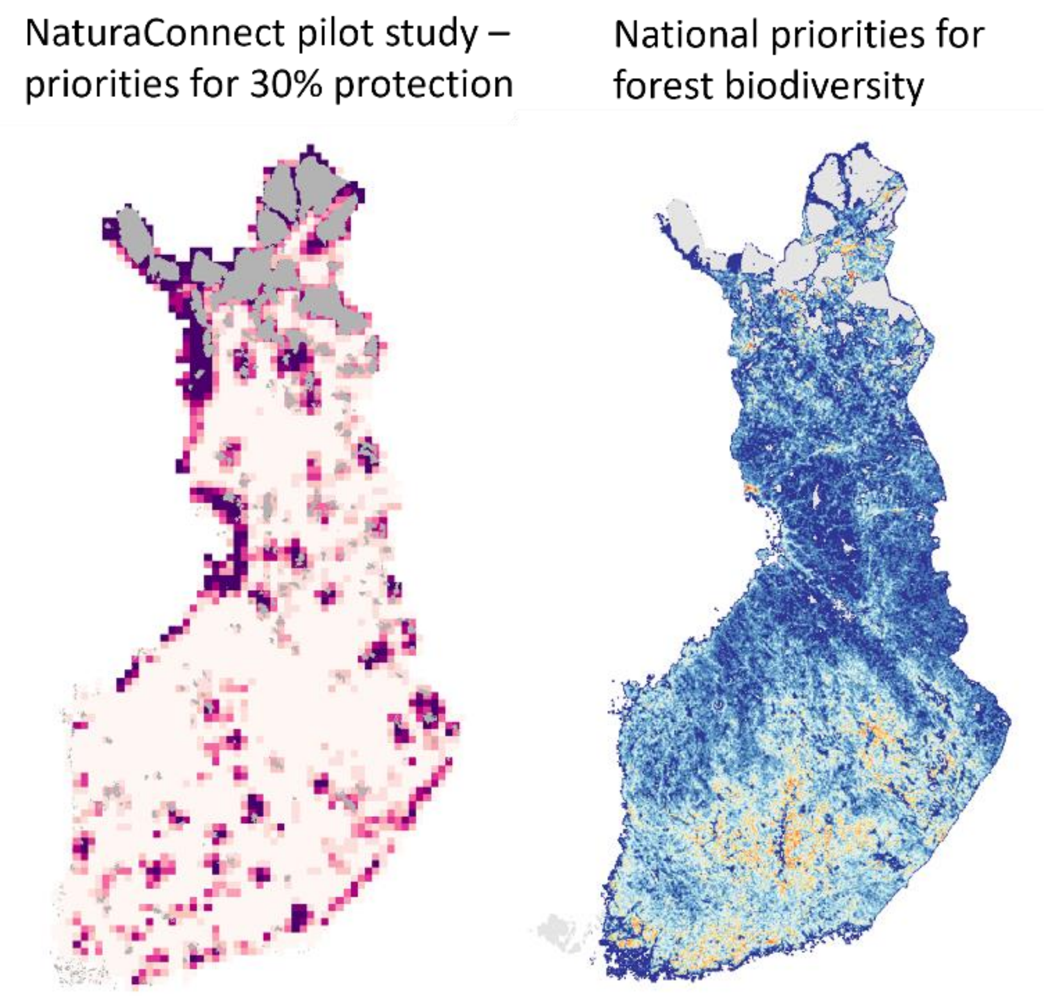

Figure 6. Emerging differences between European level and national priorities. On the left, priority areas for conservation in Finland needed to achieve 30% conservation target for the EU, based on NaturaConnect pilot study. The purple colours indicate the proportion of grid cell (10x10km) suggested to be protected. On the right, national priorities for protecting forest biodiversity, at 96x96 m resolution. Colours indicate level of priority for protection, ranging from blue (low priority) to red (high priority). Note that this map does not show which areas are needed to achieve 30% area protection at national level. Currently strictly protected areas are shown in grey in both maps. Priority areas have been identified so that they complement current protection. These two results are based on different data, taxa, resolution and optimization methods and they focus on different environments (NaturaConnect: all terrestrial environments, national prioritisation: only forests), but illustrate some of the starting points of comparing European and national level conservation needs examined in this case study.

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3.6. References

Forsius, M., Holmberg, M., Junttila, V., Kujala, H., Schulz, T., Paunu, V.V., Savolahti, M., et al. (2023) Modelling the regional potential for reaching carbon neutrality in Finland: sustainable forestry, energy use and biodiversity protection. Ambio, 52, no. 11: 1757–76. https://doi.org/10.1007/s13280-023-01860-1 .

Kareksela, S., Aapala, K., Alanen, A., Haapalehto, T., Kotiaho, J. S., Lehtomäki, J., Leikola, N., et al. (2020) Combining spatial prioritization and expert knowledge facilitates effectiveness of large-scale mire protection process in Finland'. Biological Conservation, 241: 108324. https://doi.org/10.1016/j.biocon.2019.108324.

Kotiaho, J.S., Ahlvik, L., Bäck, J., Hohti, J., Jokimäki, J., Kallio, K.P., Ketola, T., et al. (2021) Metsäluonnon turvaava suojelun kohdentaminen Suomessa. Suomen Luontopaneelin julkaisuja. https://doi.org/10.17011/jyx/SLJ/2021/4.

Kukkala, A.S., Arponen, A., Maiorano, L., Moilanen, A., Thuiller, W., Toivonen, T., Zupan, L., Brotons, L. and Cabeza, M. (2016) Matches and mismatches between national and EU-wide priorities: examining the Natura 2000 network in vertebrate species conservation. Biological Conservation, 198: 193–201. https://doi.org/10.1016/j.biocon.2016.04.016.

Mikkonen, N., Leikola, N., Halme, P., Heinaro, E., Lahtinen, A. and Tanhuanpää, T. (2020) Modeling of Dead Wood Potential based on tree stand data. Forests, 11, no. 9: 913. https://doi.org/10.3390/f11090913.

Mikkonen, N., Leikola, N., Lehtomäki, J., Halme, P. and Moilanen, A. (2023) National high-resolution conservation prioritisation of Boreal forests. Forest Ecology and Management, 541: 121079. https://doi.org/10.1016/j.foreco.2023.121079.

Minunno, F., Peltoniemi, M., Härkönen, S., Kalliokoski, T., Makinen, H. and Mäkelä, A. (2019) Bayesian calibration of a carbon balance model PREBAS using data from permanent growth experiments and national forest inventory. Forest Ecology and Management, 440: 208–57. https://doi.org/10.1016/j.foreco.2019.02.041.

Moilanen, A., Lehtinen, P., Kohonen, I., Jalkanen, J., Virtanen, E.A. & Kujala, H. (2022) Novel methods for spatial prioritization with applications in conservation, land use planning and ecological impact avoidance. Methods in Ecology and Evolution 13(5): 1062–72. https://doi.org/10.1111/2041-210X.13819.

Virkkala, Raimo, Niko Leikola, Heini Kujala, Sonja Kivinen, Pekka Hurskainen, Saija Kuusela, Jari Valkama, and Risto K. Heikkinen. 'Developing Fine-Grained Nationwide Predictions of Valuable Forests Using Biodiversity Indicator Bird Species'. Ecological Applications 32, no. 2 (2022): e2505. https://doi.org/10.1002/eap.2505.

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4. France case study

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4.1. Background

In 2010, the Parties to the Convention on Biological Diversity adopted in Nagoya (Japan) the Strategic Plan for Biodiversity 2011-2020 and its 20 so-called Aichi Targets to ensure the loss of biodiversity. France has transposed this international framework into its national Biodiversity Strategy, and notably through its protected area national plan aiming at re-enforcing and expanding protected area network (Aichi target 11). The National Strategy for Protected Areas 2030 (first strategy published in 2009, updated in 2020), based on an ambitious program of 7 objectives and 18 measures, principally aims at improving both the quality and quantity of protected lands through better management and connectivity of protected areas including mitigation and adaptation to climate changes. This national strategy also meets the European ambition to reach 30% of protected land including 10% under strict protection. The Ministry of Ecological Transition has enlisted the French Biodiversity Agency (OFB) for the development and implementation of this strategy, which will ensure its coordination, monitoring and evaluation (More details can be found here: https://inpn.mnhn.fr/programme/espaces-proteges/strategie-aires-protegees?lg=en).

4.2. Identification of conservation planning challenges

Hexagonal France hosts various ecosystems and very different landscapes from four biogeographical regions (Atlantic, Continental, Alpine and Mediterranean, Fig. 1). About 100 000 species are identified in metropolitan France including more than 2400 threatened species, and 7000 under protection. France is the 6th country hosting the highest number of threatened species according to the IUCN red list. French territory faces human pressures including natural habitat loss, overexploitation of natural resources, climate change, pollution and invasive and alien species.

The French protected area network is made of a plurality of tools for biodiversity conservation: Metropolitan France counts 5913 protected areas classified in 27 categories and including 1619 strict protections. Metropolitan France is covered at 28.1% by protected areas, accounting for 1.6% of strict protections (Protection cover references can be found here: https://inpn.mnhn.fr/espace/protege/indicateur/recherche)(Fig. 2). Consequently, strict protections will be the target of network expansion. For an area to be classified as strict protection, the level of human pressure should be limited. Notably, a list of excluded human pressures in strict protections is about to be created (e.g., industrial, commercial or residential infrastructures, intensive agriculture, fertilizers). Note however, that some pressures are still allowed in some strict areas (e.g., hunting, fishing, forestry). Integral biological reserves are the only areas where all human activities are forbidden. Designation of new strict protections

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will imply some challenges and thereby will be done on a case-by-case basis, likely involving already protected areas with non-strict status.

Figure 1. Metropolitan France counts four biogeographical zones creating a puzzle of landscapes and ecosystems.

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Figure 2. Distribution of protected areas in metropolitan France. Map taken from https://inpn.mnhn.fr/docs/communication/Carte-Panorama-biodiversite-et-aires-protegees-2020-IGN.pdf

4.3. Stakeholder engagement

The French Biodiversity Agency (Office Français de la Biodiversité, OFB) plays a major role for the protection and restoration of the biodiversity through various programs, actions and expertise development all over the territory (https://www.ofb.gouv.fr/en). Notably, they provide support for public policies, manage different types of protected areas, bridge over the gap between policy-makers and researchers and disseminate knowledge towards multi-operators, and consequently emerge as highly relevant and multifaceted stakeholders for the French case study of the NaturaConnect project (Fig. 3).

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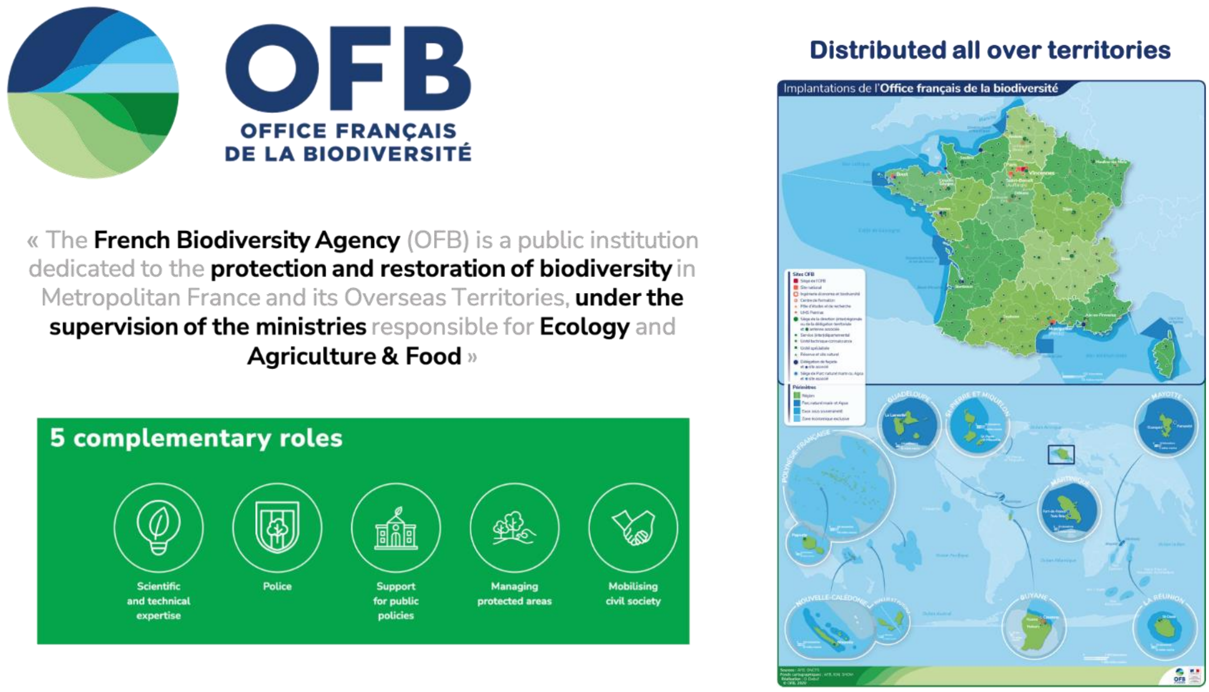

Figure 3. French Biodiversity Agency presentation.

In May 2024, the French case study launched its first stakeholder engagement event gathering 18 participants from the French Ministry of Ecological Transition, three different Regional Direction for the Environment, Planning and Housing (DREAL) and the French Biodiversity Agency. A full day of scientific presentations and exchanges around the National Strategy for Protected Areas.

France aims at strictly protecting 10% by 2030, through the prioritization of already protected areas showing low level of anthropogenic pressures. Regional authorities have strong power to designate protected land and are very keen to learn from the NaturaConnect consortium work and material.

4.4. Case study objectives and expected outcomes

The general purpose of this case study is to provide analytical support necessary to meet the national protected area strategy requirements for metropolitan France in terms of knowledge on biodiversity distribution, connectivity of protected areas and systematic conservation planning. The results will be directly disseminated towards multi-operators including park managers, policy-makers, biodiversity experts or the general public. They should particularly provide important tools to leverage environmental strategies for spatial planning.

We are engaging with the OFB through a three-years cooperative partnership involving relevant stakeholders. This partnership follows up a previous partnership started in November 2021 for two years between the Alpine Ecology Lab (Wilfried Thuiller, LECA) and the French Biodiversity Office (Florian Barnier, OFB) aiming at developing a methodological framework to predict the current distribution of species and community at high resolution all over the metropolitan France (Fig. 4).

We plan to work on two tasks during this new partnership notably 1) using the validated models from the first partnership to predict future species and community distribution and 2) assessing current and future connectivity of protected areas in metropolitan France. Future scenarios will take into account both climate and land-use changes and will stem from the work packages 3 and 5 of NaturaConnect. Three taxonomical groups will be studied in these analysis

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including vertebrates, invertebrates and plants with particular interests on specific subgroups (notably for plants and invertebrates) based on their level of knowledge and conservation concerns they raised. Besides, a list of patrimonial species at the national scale (thereafter named SNAP species) including vertebrates, invertebrates and plants will stand high priority in the analysis.

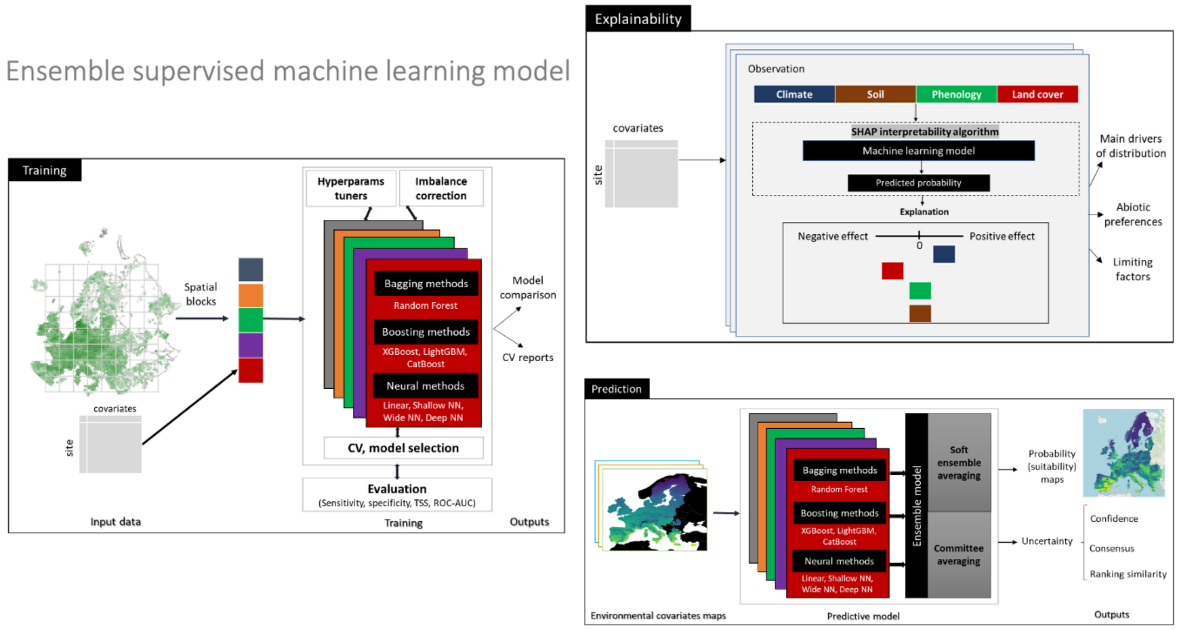

Figure 4. General modelling framework developed to predict current biodiversity distribution at both the European and metropolitan France scales (from previous partnership between the CNRS and the OFB).

4.5. Methodological approaches

4.5.1. Task 1 - Modelling biodiversity in metropolitan France

This task will be divided into three sub-objectives including 1) the validation of the distribution models developed during the first partnership between the LECA and the OFB from expert knowledge, 2) the use of the validated models to predict future biodiversity distribution from several scenarios and 3) the dissemination of the results through the National Inventory of Natural Heritage (INPN) website, handled by the OFB (https://inpn.mnhn.fr/accueil/index?lg=en). Several databases (e.g., GBIF, IUCN, iNaturalist, group specific datasets, national inventory, etc.) will be considered for the analysis to be as exhaustive as possible. Besides, distribution models will be fitted at the European scale to encapsulate the whole ecological niche of each species and provide more realistic future predictions.

Sub-task 1.1 Current model validation and improvement

The first partnership between the LECA and the OFB (ending in November 2023) aimed at 1) selecting species with enough occurrence data to be able to run their distribution model, 2) identifying relevant environmental variables for those species and 3) fitting current distribution models for the selected species. In this sub-task, the outputs (i.e., maps of potential presence) of the current distribution models will be assessed by different groups of experts, coordinated by the OFB, and if needed the distribution models will be consolidated.

Selected species that will be modelled are the following:

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	Groups	Number of species
Vertebrates	Amphibia	127
	Aves	532
	Mammalia	310
	Reptiles	290
Invertebrates	Araneae	914
	Carabidae	472
	Formicidae	128
	Gastropoda	303
	Lepidoptera	3 776
	Odonata	136
	Orthoptera	314
	Syrphidae	356
Vascular plants	Lilianae	2786
	Lycopodiophyta	25
	Dicotyledones	14 445
	Pinopsida	91
	Monilophyta	190

Sub-task 1.2 Modelling future biodiversity in metropolitan France

Validated models from sub-task 1.1 will be used to project species distribution in the future from several scenarios of climate and land-use changes. Scenarios RCP2.6 and 7.0 for climate and SSP1 (and perhaps their derivative NFFs) and SSP3 for land-use (from WP5) will be notably used for the future. Projected distribution maps will be further used to provide maps of distributional changes for each species and aggregated maps of evolution in species diversity and composition as a function of the different future scenarios. Consequently, these indicators could provide multiple risk-assessments entailed by the French biodiversity at the metropolitan scale. A reflection will be initiated on how to translate these global change-related risk-assessments into evaluation criteria such as the one used for the red lists and could result in the creation of a species orange list, an anticipatory list of species that could become classified along the IUCN criteria for the future.

Sub-task 1.3 Disseminating current and future biodiversity distribution

All maps produced in sub-tasks 1.1 and 1.2 will be made available on the INPN website for anyone, free of downloading. The maps will be standardized and provided with a technical report to make them reusable. The OFB will be in charge of the dissemination of the maps and their maintenance. Notably, all scripts generated during sub-tasks 1.1 and 1.2 will be shared with the OFB and training will be organized for the scripts to be regularly updated together with the produced maps.

4.5.2. Task 2 - Assessing connectivity of protected areas in metropolitan France

In this task, we will first develop a robust methodological framework to assess protected area's connectivity over the French metropolitan territory. This framework will then be applied to all SNAP species to evaluate both current and future connectivity of protected areas. Future scenarios will reflect changes in climatic conditions and land-use, and will be the same

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as the one used in task 1. Finally, different indicators of connectivity will be produced that are needed to meet the requirements of the National Strategy for Protected Areas.

Sub-task 2.1 Developing a robust framework to assess protected areas' connectivity

The objective of this task is to develop a versatile and robust framework that can be applied to a large range of taxonomic groups in current and future environmental conditions. Besides, this framework should provide indicators of connectivity that are relevant for spatial planning policy. Species archetypes will be first generated from species' characteristics, including morphological, biological and ecological traits and niche distribution. These archetypes will reflect functional groups composed of similar species. Then, resistance matrices to movement will be estimated for each group from habitat suitability modelling and further used to produce continuous connectivity maps over the metropolitan France. Finally, these maps will be dichotomized and crossed with the distribution of protected areas to extract connectivity metrics with their uncertainty. The selection of connectivity indicators will be done in tight interaction with the OFB to maximize their relevance for application purpose. This methodological framework will be first applied to vertebrates of the SNAP species list as a proof-of-concept.

Sub-task 2.2 Application of the robust framework within the context of the National Strategy for Protected Areas

The framework developed in sub-task 1 will be first applied to all SNAP species using current environmental conditions. We will then evaluate how protected areas 1) are connected considering different networks (e.g., strong protection only VS all protected areas) and 2) contribute to the protection of movement corridors for wild species. This analysis will also be useful to identify protected areas that lack connection with others and for which spatial planning policy would be highly relevant. Finally, the framework will be used to evaluate how protected areas will be connected considering future changes and notably whether species will be able to reach future suitable habitats.

4.6. Operational aspects

Timeline

The partnership between the LECA and the OFB started on December, 1st 2023 and should last 3 years.

Work tasks	**S1** *12/2023 - 05/2024*	**S2** *06/2024 - 11/2024*	**S3** *12/2024 - 05/2025*	**S4** *06/2025 - 11/2025*	**S5** *12/2025 - 05/2026*	**S6** *06/2026 - 11/2026*
Task 1. Biodiversity distribution	X	X	X	X		
Sub-task 1.1 Model validation	X	X				
Sub-task 1.2		X	X			

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Future distribution						
Sub-task 1.3 *Diffusion*						
Task 2. **Connectivity of protected areas**						
Sub-task 2.1 *Methodological development*						
Sub-task 2.2 *Application*						

4.7. Preliminary results

Sub-task 2.1 Developing a robust framework to assess protected area's connectivity

A comprehensive framework to assess multi-species landscape connectivity for spatial planning has been developed and is currently under review in *Methods in Ecology and Evolution*. This framework has been developed in strong interactions with our stakeholders and WP6, and is based on four steps (Fig. 5):

- Step 1. Clustering species in functional groups having similar traits and environmental niches;
- Step 2. Generating resistance and habitat suitability maps for each group based on an ensemble of species distribution models;
- Step 3. Generating ecological continuities (i.e., landscape elements contributing to ecological connectivity) per group;
- Step 4. Calculating multi-scale protected area network metrics.

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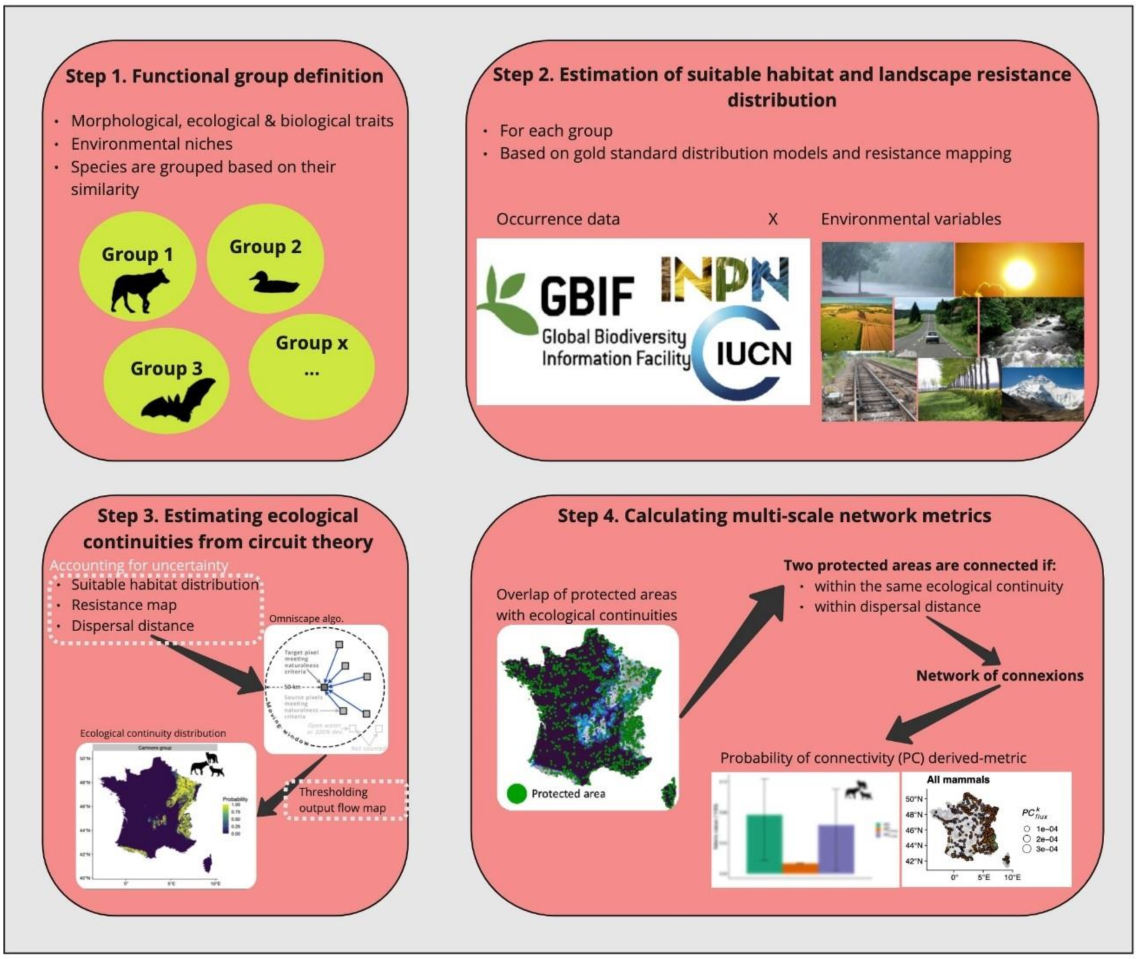

Figure 5. General steps of the methodological framework developed in WP8.3 to assess multi-species landscape connectivity for spatial planning application.

Our framework integrates three key innovative components: (1) the empirical grouping of species based on environmental niche overlap and shared morphological, ecological and biological traits for dimension reduction; (2) the derivation of multi-scale network-based connectivity metrics using continuous estimates of ecological continuities and dispersal capacity, allowing consideration of diverse pathways without constraining movement among pre-defined conservation areas; and (3) the incorporation of parameter uncertainty in the estimation of ecological continuities and connectivity metrics.

As a proof-of-concept, we applied our framework to assess the current connectivity (i.e., considering the 2010-2020 period) of 1619 protected areas in metropolitan France for 193 vertebrate species, including 52 mammals and 141 birds. Species were selected for their conservation importance including endemic species, species of the Birds and Habitats directives (annexes I, II and IV) and threatened species (CR, EN and VU categories) according to the European or national IUCN red lists. Protected areas included national parks, national and regional natural reserves, biological reserves, prefectural biotope protection order, prefectural geotope protection order and prefectural order for natural habitat protection. These protections encompass strict protections having reglementary land management that excludes or reduces human activities within sites.

From the 193 vertebrate species, our clustering approach identified 11 groups of mammals and 19 of birds having similar environmental niche and morphological, biological or ecological traits (Fig. 6). Overall, we found the spatial distributions of ecological continuities in

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metropolitan France for our 30 vertebrate groups to be considerably heterogeneous across groups (Fig. 7) and poorly covered by the current distribution of protected areas (average 3.1%), with again notable variation among groups (Fig. 8). Connectivity of group-specific suitable habitat through protected areas was generally low, with the global probability of 2 suitable locations to be within connected protected areas never exceeding 3.0% (Fig. 9). Local connectivity metrics identified the contribution of different types of protections to overall landscape connectivity for the 193 evaluated vertebrate species. Intra-site connectivity was mainly driven by national parks (likely due to their large size), although natural or biological reserves influenced some groups (Figs. 10 & 11). Connectivity of protected suitable habitat through direct or indirect connections of protected areas involved both the national parks and natural or biological reserves (Figs. 10 & 11). Finally, natural or biological reserves and prefectural protection orders acted as stepping stones to connect protected suitable habitat for most evaluated mammals and birds (Figs. 10 & 11).

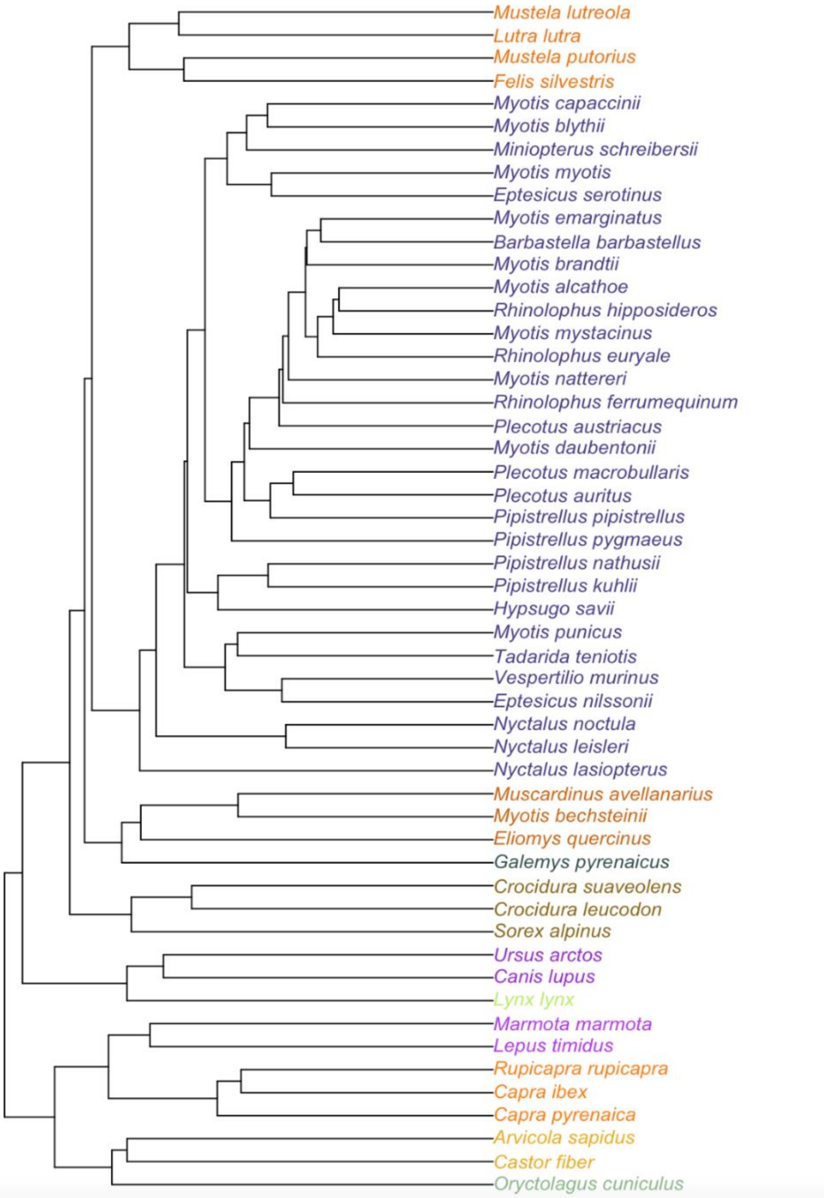

*Figure 6. **Group composition for mammals**. See the full version of the paper for bird group composition.*

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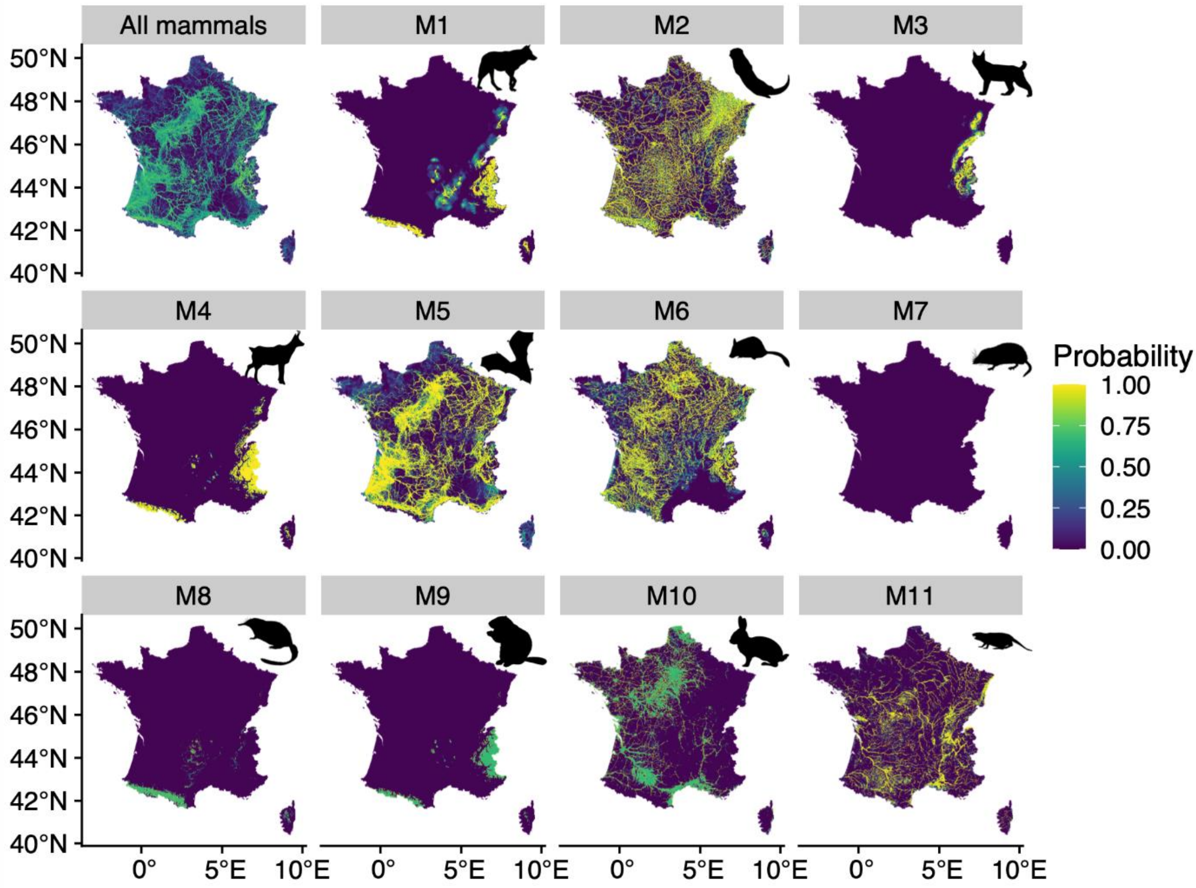

Figure 7. ***Distribution of ecological continuities for mammals in metropolitan France considering the 2010-2020 period****. M1 to M11: mammal group ID, see the full version of the paper for detailed group composition.*

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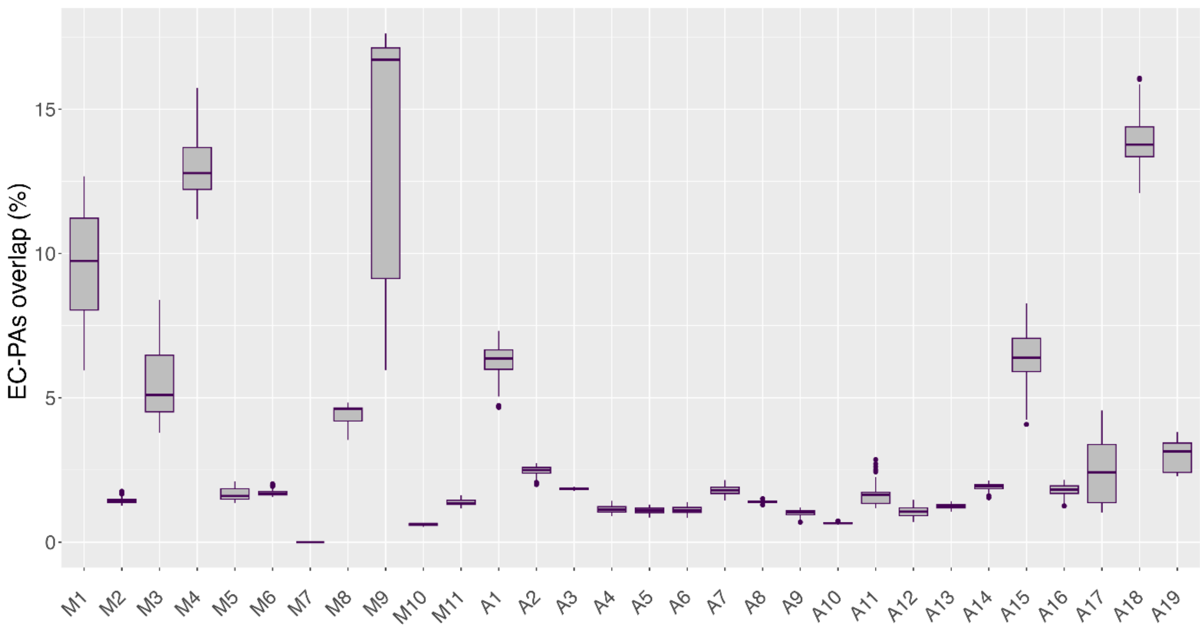

Figure 8. ***Percentage of overlap of ecological continuities by strict protections in metropolitan France considering the 2010-2020 period for 30 vertebrate groups.*** *M1 to M11: mammal group ID, A1 to A19: bird group ID, see the full version of the paper for detailed group composition.*

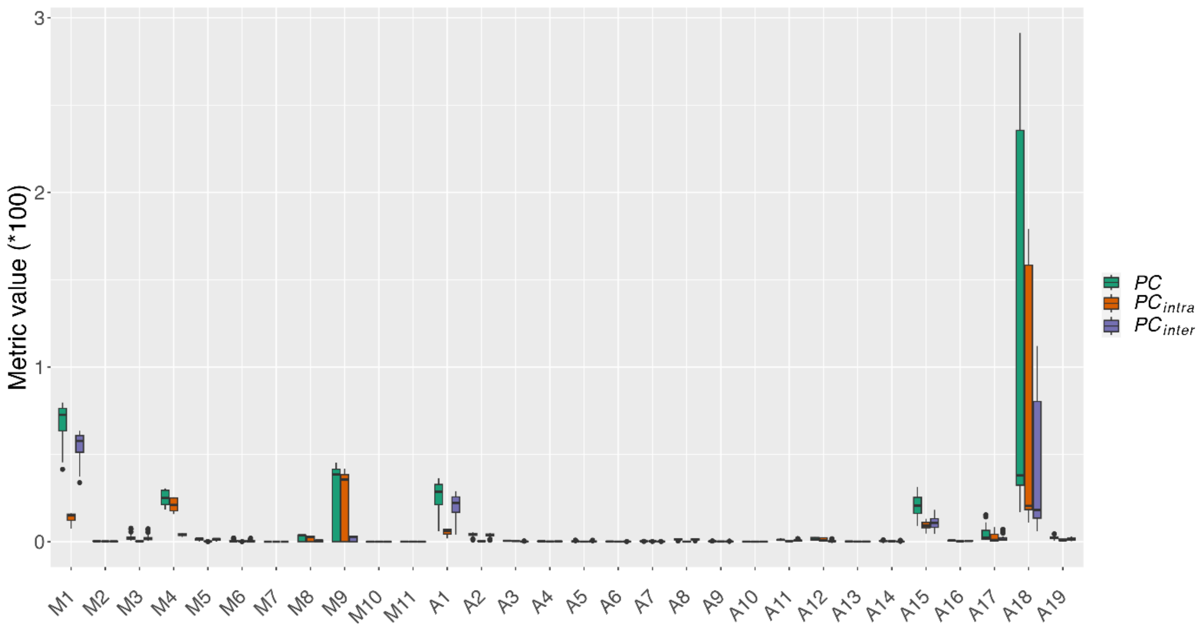

Figure 9. ***Global probability of two suitable locations to be within connected protected areas in metropolitan France considering the 2010-2020 period for 30 vertebrate groups.*** *M1 to M11: mammal group ID, A1 to A19: bird group ID, see the full version of the paper for detailed group composition. PCintra reflects intra protected area connectivity while PCinter reflects inter protected area connectivity. PC is the sum of PCintra and PCinter*.

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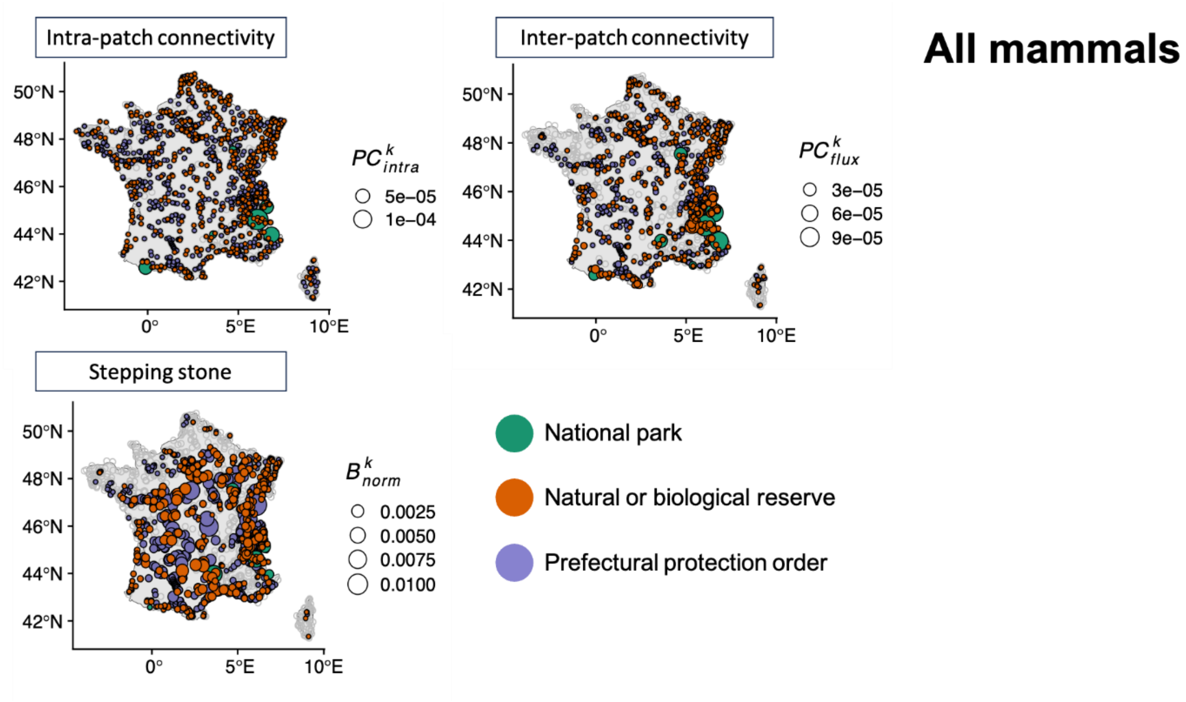

Figure 10. Level of connectivity of each protected area and contribution as stepping stone in metropolitan France considering the 2010-2020 period for 52 mammal species.

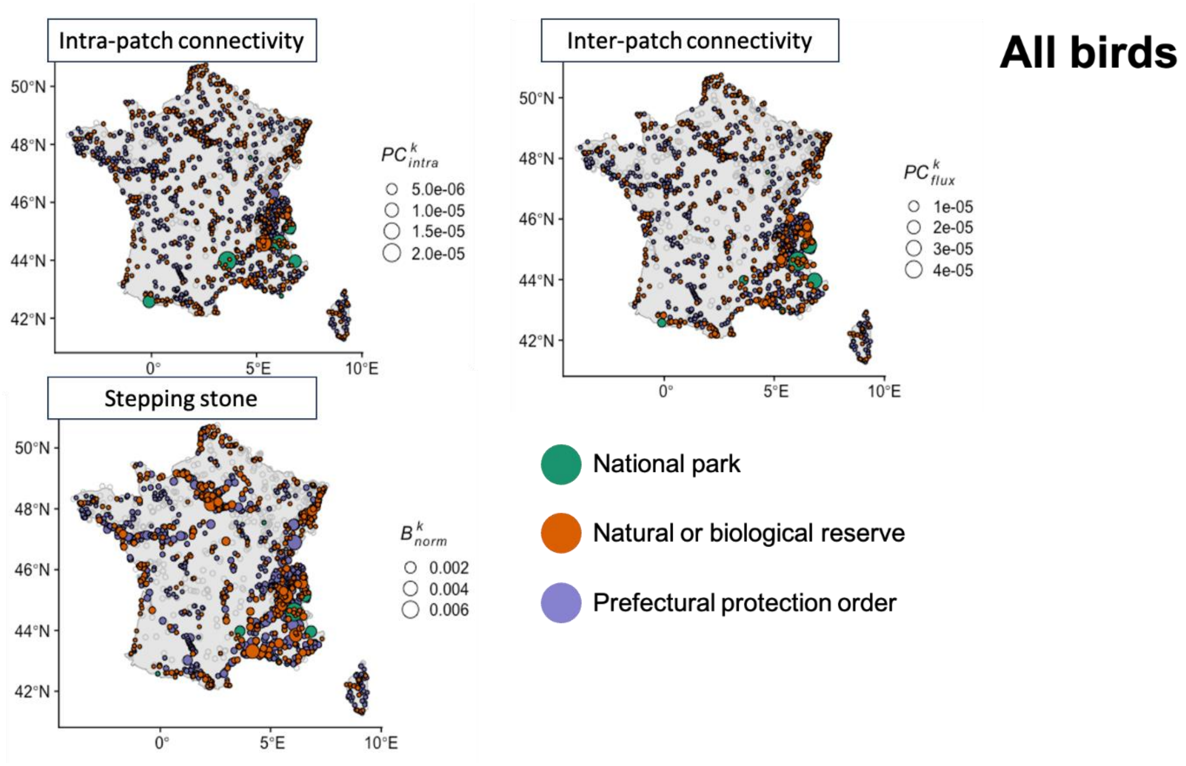

Figure 11. Level of connectivity of each protected area and contribution as stepping stone in metropolitan France considering the 2010-2020 period for 141 bird species.

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In light of the EU Biodiversity Strategy for 2030, aiming to protect at least 30% of the territory by 2030, with 10% under strict protection, we found that strictly protected areas in metropolitan France are inadequately protective of vertebrate ecological continuities and poorly connected. Protected area connectivity could notably be enhanced based on a strategic expansion of protected areas and via the restoration of ecological corridors among disrupted ecological continuities. Our maps of ecological continuities provide notably valuable information for selecting potential areas to protect and restore. More generally, our flexible framework to evaluate landscape connectivity in heterogeneous environments should contribute to more informed decision-making in spatial conservation planning. Accounting for biodiversity representativeness, functional landscape use, and uncertainty in model parameters, our approach is adaptable to various environmental conditions, including future global changes. Finally, we urge that the strategic expansion of protected areas and the restoration of key ecological corridors emerge as a priority to enhance landscape connectivity and support biodiversity conservation efforts in metropolitan France.

Data and code sharing

The source code is available here: https://github.com/mcpri3/RFLC-SCP. Our stakeholders were trained to the use of the code during a one-day session (14/03/2024) for them to be able to run it as wanted.

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5. Portugal case study

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5.1. Identification of conservation planning challenges

Portugal holds significant ecological diversity, influenced by the confluence of the Atlantic and Mediterranean climates and distinctive biogeographic conditions. Despite the expansion of marine and terrestrial protected areas in recent decades, the overarching trend continues to be the loss of biodiversity and the degradation of ecosystem services, as in many other EU countries. Numerous priority habitats and species remain in unfavorable conservation status. Reversing the degradation of ecosystems and slowing down the dashing loss of biological diversity will require a multi-sectoral approach involving both the public and the private sectors, especially relevant in Europe's country with the highest percentage of private forest land (over 84% privately owned, 13% community land, only less 3% is public).

By 2030, Member States are required to expand the network of protected areas, promoting connectivity and ecological restoration, to guarantee a legal protection status for 30% of their territory (maritime and terrestrial), of which one-third should have strict protection. The creation of a truly coherent Trans-European Nature Network (TEN-N) is one of the objectives of the EU Biodiversity Strategy for 2030. In Portugal, protected areas (including Natura 2000 sites) cover 22,5% of the total terrestrial area and 10.7% of the marine area; however, only 0,17% of land and 0,001% of the Exclusive Economic Zone are strictly protected.

In November 2023, the Portuguese Government announced the inclusion of Ramsar Sites, UNESCO Biosphere Reserves and UNESCO Geoparks in the network of "classified areas" with legal protection status. This resolution of the Council of Ministers is a significant stride, resulting in the expansion of protected areas (PA) to 34,8%, and thus, enabling Portugal to meet the 30% target. However, the decision lacked scientific grounding on ecological and climate connectivity, and management plans with the necessary conservation measures still need to be produced for these areas. Reaching the 10% target of strict protection entails a significantly complex exercise, that will require multilevel solutions and the implementation of various legal instruments.

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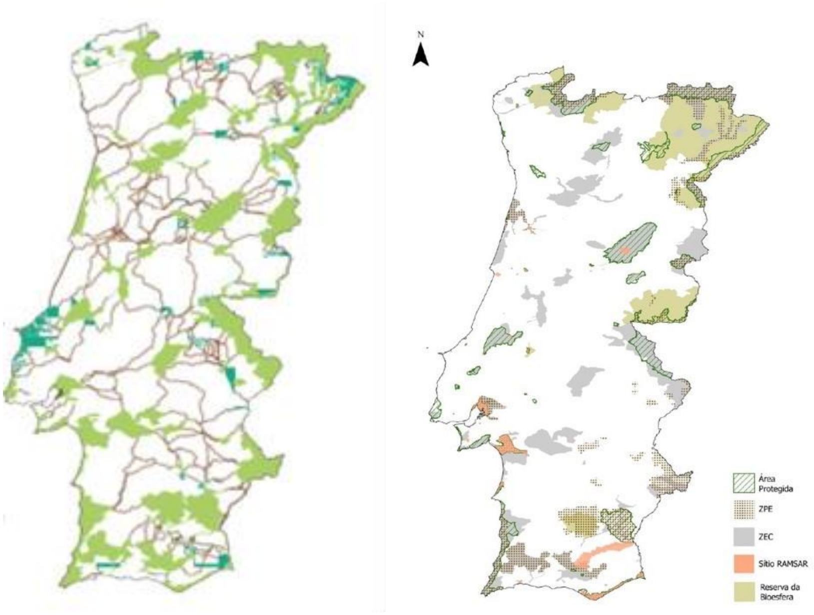

Figure 1. On the left - the existing classified areas in Portugal (including protected areas and Natura 2000 sites), before the Council of Ministers' resolution; climate corridors (red line) and climate refuges (dark green). On the right - existing classified areas, Ramsar sites and MaB Reserves, following the resolution. Comparison between both maps shows a low overlap between science-based proposals and political decisions.

The scientific study published in 2022 "Biodiversity 2030 - a new agenda for conservation in the context of climate change", coordinated by Miguel Bastos Araújo (NaturaConnect partner, UEV), provides an analysis of terrestrial and marine biodiversity patterns and trends, considering climate change scenarios projected for Portugal. It diagnoses trends and vulnerabilities and proposes an agenda to technically, administratively, and financially strengthen biodiversity conservation and restoration policies in mainland Portugal and its marine territories. Based on geographical biodiversity data from land, inland waters, and the sea, the report aimed to generate scenarios to support political decision-making processes. Legislation, land planning tools, socio-economic trends and funding for biodiversity were analysed, to identify opportunities that can leverage biodiversity and associated ecosystems services, with proposed measures for ecological connectivity in the context of climate change. It also proposes a package of measures and policies to reverse the trend of degradation and loss of natural capital.

The main challenges identified in the report include:

- Lack of consideration of threats arising from climate change and biodiversity loss in conservation planning;
- Prevalence of passive biodiversity management, which limits the ability to maintain and restore populations and ecosystems;
- Access to centralised data and limited availability to characterise biodiversity trends and vulnerabilities.
- Poor intersectoral and interministerial coordination, both on land and at sea, resulting in ineffective use of public funds;
- Limited capacity building and empowerment of local actors in active natural capital management, which restricts effective territorial intervention;

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- Chronic underfunding of public conservation policies;
- Limited involvement of the private sector in funding biodiversity.

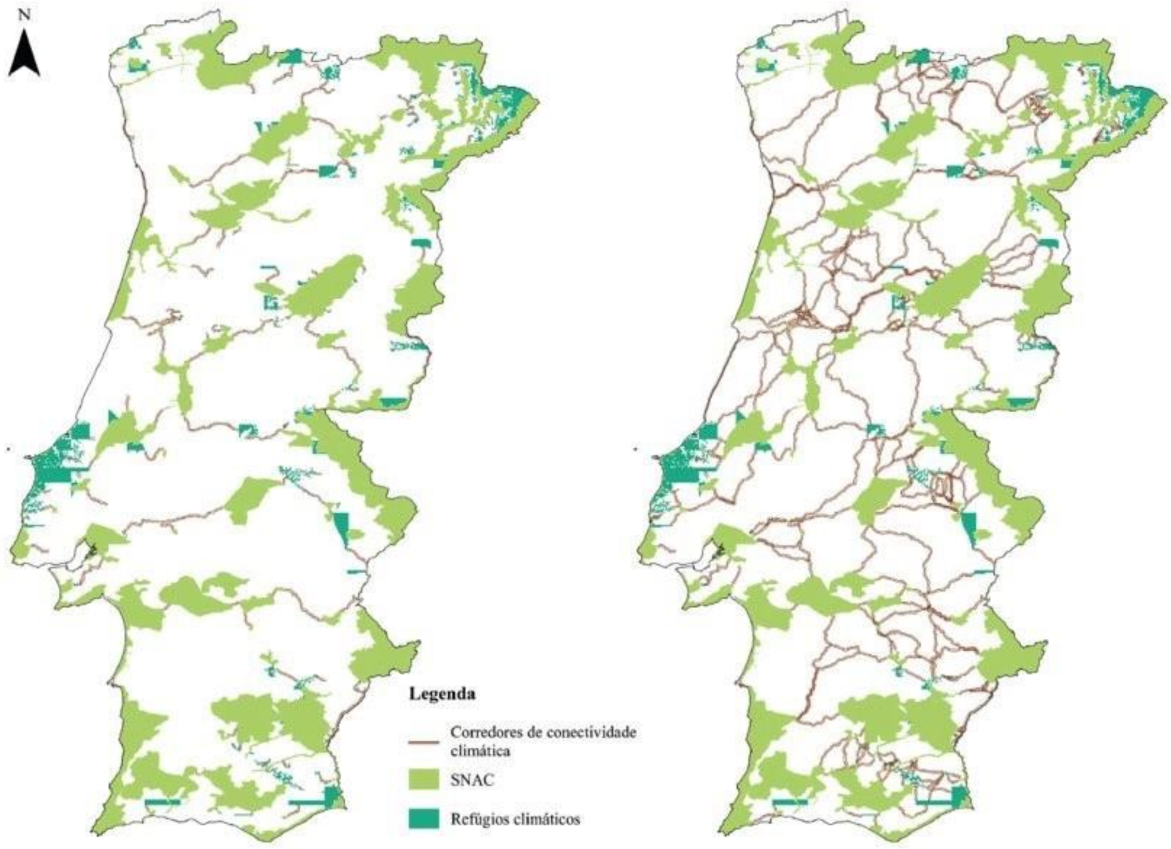

Figure 2. Constrained by RCP 6.0; Minimum set 500 km2 target per species. Red line – corridors for climate connectivity; light green: Classified Areas in Portugal (including protected areas and Natura 2000); darker green: climate refuges. Araújo et al. 2022.

5.2. Case study objectives

Building upon the robust science-based report, the Portuguese Case Study aims to create a blueprint for ecological connectivity in Portugal, working on the complex socio-economic and political context. By bringing people together in high-level debates, informative sessions and workshops, the case study promotes cross-pollination between key stakeholders from the public administration, third sector, universities and businesses, to drive effective policy changes and practical actions to effectively meet the targets of the EU Biodiversity Strategy for 2030. The objectives of the case study include:

- Identify, collaboratively, barriers and needed actions to meet the targets set in the EU Biodiversity Strategy for 2030;
- Understand the main nodes of the regulatory system (for nature conservation and spatial planning) and the interrelationships established between them;

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- Enhance positive synergies and interinstitutional relations within the public administration and the private sector;
- Define, collectively, intervention priorities to unlock legal, economic and social barriers for the implementation of the EU Biodiversity Strategy for 2030;
- Enhance technical expertise and provide learning and knowledge-sharing opportunities for professionals engaged in nature conservation and spatial planning professionals, spanning across local, regional and national levels.

5.3. Stakeholder engagement

The work of the Portuguese case study requires a direct engagement of multiple stakeholders from both the private and public sectors, including organisations with technical, statutory and legal influence in biodiversity conservation, environment, PA management and spatial planning. From the Public Administration, there was a direct involvement of the (former) Minister for the Environment and Climate Action, who approved and supported the creation of the NaturaConnect Think Tank, a working group comprising influential decision-makers from public institutions, universities, businesses and NGOs. To increase technical capacity in ecological connectivity, technicians working in land planning and nature conservation working at regional level are being involved in informative and capacity-building sessions.

Table 1. Stakeholders involved in the Portuguese case study

National public authorities	Ministry of Environment and Climate Action; State-Secretariat for Nature Conservation and Forests; ICNF - Nature Conservation and Forests Institute; APA - Portuguese Agency for the environment; DGT - Directorate-General for Spatial Planning; Directorate-General for Agriculture and Rural Development.	High interest High influence
Regional public authorities	Regional Secretariat for the Environment and the Sea (Azores); Madeira Natural Park Service; Mainland Portugal: CCDR - (5) Commission for Regional Coordination and Development; CIM - Intermunicipal Communities	High interest Medium influence
Regional public authority	Directorate-General for Regional Planning and Urban Development	
Local public authority	Municipalities; Associations of Municipalities	
Research	Évora University; Biopolis - CIBIO - Research Institute U. Porto; MED - Mediterranean Institute for Agriculture, Environment, and Development of the University of Évora; Institute of Social Sciences of the University of Lisbon; iDiv	High influence in the delivery of planned activities
Sectoral Agency	FlorestGal - Public company for forest management; Parques of Sintra; Mafra National Reserve	High interest Medium influence
NGOs and Trusts	Mata do Buçaco Foundation; LPN - Nature protection; Rewilding Portugal; ANP/WWF Portugal; Gulbenkian Foundation; National and regional environmental NGOs	
Sectoral Agency	BCSD - Business Council for Sustainable Development;	Medium interest Medium influence
Enterprises	SONAE (retail); E-Redes (energy); Navigator (paper production); businesses committed to biodiversity conservation	
Media	media outlets, regional and national	

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5.4. Methodological approaches

Analysing barriers and opportunities

The NaturaConnect Think Tank was established to promote interinstitutional cooperation in identifying barriers and developing innovative solutions for implementing the TEN-N in Portugal. Comprising high-level representatives from the private and public sectors, the group serves as a dialogue platform on the political, socio-economic and technical challenges. Throughout the project duration, the Think Tank will gather three times for thematic discussions, delving into the EU Biodiversity Strategy implementation in Portugal, the expansion and coherence of the PA network, guidelines and funding strategies for natural capital, biodiversity and ecological restoration. The Think Tank will produce recommendations to influence decision-making processes, which will be shared with Parliamentary groups, media outlets and other organisations with strong influence on the topics covered.

Delivering informative sessions and capacity-building events

Targeting technicians working for the public administration at the local, regional and national levels, but also other organisations relevant to nature conservation and spatial planning in Portugal, three informative sessions will be held online. The half-day thematic sessions, open to the wider public, will cover specific topics with relevant experts and invited organisations, who will share results and inspire participants with their experiences. Themes include spatial planning legal instrumental for ecological connectivity, strategies for funding biodiversity, and nature restoration.

Increasing capacity at the technical level is one of the objectives of the Portuguese case study. Four workshops will be structured and delivered to professionals of the key target audiences identified. An opportunity to bridge scientific knowledge between national authorities, with the outputs of the Think Tank and the NaturaConnect project. Planned for small groups, the workshops will provide an immersive experience of two days, to share the necessary tools and empower participants to take action in spatial conservation planning, active and effective management of protected areas, nature restoration and biodiversity monitoring. Think Tank members will be directly involved in the development and delivery of the informative and capacity-building sessions.

Reaching out to target audiences

To promote the informative sessions and workshops, targeted communications are being sent out. Potential participants, particularly those in regional public administrations, receive direct email invitations. The first informative session focused on Spatial Planning, received 430 registrations, with participants indicating a strong interest in being informed about future initiatives. These contacts have been added to the project's mailing list in Portugal to promote upcoming opportunities. Additionally, Think Tank members, representing key authorities in spatial planning and nature conservation, serve as disseminators for the sessions conducted during the project. Information is also disseminated via the project's online media channels, and press releases have been sent and reported by the main Portuguese media outlets.

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5.5. Preliminary results

Challenges and opportunities

With the first Think Tank meeting, focused on the analysis of the EU Biodiversity Strategy implementation in Portugal, it is possible to extract some of the main barriers and opportunities discussed. Through facilitated dialogue and work in smaller groups, participants identified key challenges for each biodiversity target, which have been clustered into thirteen main areas.

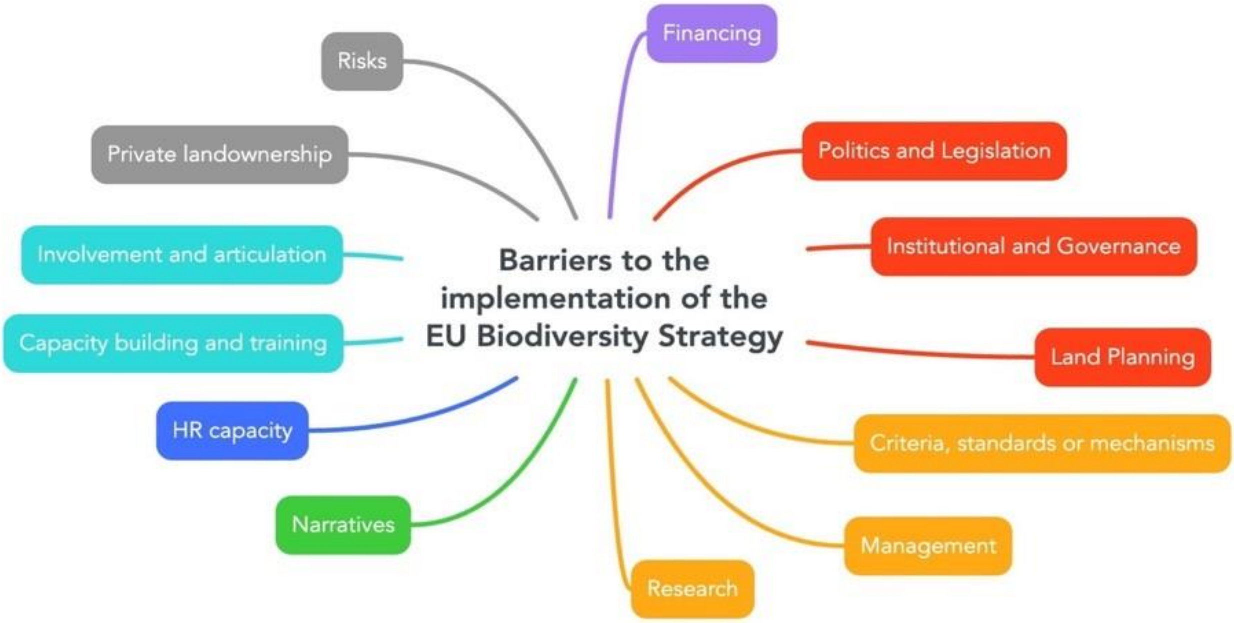

Figure 3. Clustered barriers to the implementation of the EU Biodiversity Strategy in Portugal.

The high percentage of private land ownership is one of the main barriers identified to achieve the targets of protecting 30% of terrestrial territory and 10% in strict protection. It is necessary to create fiscal incentives for private landowners and define a robust allocation of public funds for property acquisition, especially inside protected areas. The lack of funding was mentioned as one of the key barriers to achieving many other targets.

The conservation of public goods in privately owned territories brings conflicts. Governance is complex and requires the harmonisation of widely divergent interests. Weak intersectoral coordination, low involvement of stakeholders in participatory processes and the absence of a multidisciplinary co-constructed methodology for selecting conservation areas were mentioned as factors that inhibit mutual understanding. One of the proposals presented was the creation of empowered and multidisciplinary co-management committees.

It is necessary to improve natural resource management, share best practices and guidelines on nature restoration, and boost farming and forestry practices that can benefit biological diversity. In the primary sector, for instance, several incentives often have perverse consequences on biodiversity and ecological functionality. Farmers with intensive agricultural systems must accept the reintroduction of semi-natural elements and forest planning should be based on ecological suitability. Fostering dialogue to create compromise solutions between agricultural policies and nature conservation is essential.

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Specific competencies missing both in the working force of the public sector and among private landowners and managers were identified:

- Farmers (rural extension) – training in ecosystem services;
- Nature conservation technicians – training in ecosystem services, removal of invasive exotic species, governance;
- Municipalities – training in management for biodiversity;
- Law enforcement officers - training in environmental inspection;
- Business sector – training in nature-based solutions; ecosystem services; conservation and restoration actions;
- Society and school communities – environmental awareness; review of education curricula.

To strengthen the coherence of protected areas in Portugal, it is necessary to establish methodologies to evaluate the National Classified Areas System (SNAC) performance in achieving biodiversity targets. This includes assessing the extent to which SNAC covers the values needing protection, defining criteria for expansion based on biodiversity, climate scenarios and connectivity between SNAC areas, and defining principles for planning and management rules for connectivity areas (differentiating between Protected Areas and connectivity areas). It is also necessary to clarify criteria for the identification of strict conservation areas and deploy proper funding for their management. Funding instruments may include positive taxation, financial support for active management, and mechanisms for ecosystem services remuneration.

Table 3. Opportunities, in a nutshell, identified by the Think Tank members during its first session.

Financing • Purchase land for nature conservation inside protected areas or areas with high natural values; • Provide financial leverage to municipalities for planning and installing green infrastructure; • Establish a biodiversity fund and other "market incentives"; • Develop incentive mechanisms for companies: define concrete metrics for goals and fund results (e.g., biodiversity credits). *Natural Heritage management* • Forest management focused on quality and multifunctionality; • Harmonise interests between production and conservation;	*Land Use Planning* • Implement Municipal Ecological Structures; • Set goals that include small urban areas in the greening of urban zones; • Define boundaries appropriate to natural values; • Plan with the selection of areas outside the Natura 2000 Network, Ramsar sites, Biosphere Reserves, and Geoparks; • Consider ecological suitability in forest planning. • Governance • Implement participatory methodologies: involving local stakeholders in defining protected areas and implementing agricultural subsidies;

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• Soil management and minimal disturbance; • Incentive systems for agro-silvo-pastoral production models; • Utilise degraded land for the installation of solar energy parks; • Phased program for the removal of obsolete dams and other structures. *Criteria, Standards, or Mechanisms* • Measures for evaluating the performance of Protected Areas; • Criteria for compatibility between renewable energy sources and nature; • Principles for planning and management rules for connectivity areas; • Establish data-sharing mechanisms between companies; • Define objectives, reference systems, and monitoring methods for nature restoration; • Recognition of OECMs (Other Effective Area-based Conservation Measures); • Standardise monitoring methods; • Develop methodologies and tools for valuing natural capital and ecosystem services.	• Review the co-management model of Pas and define empowered and multidisciplinary co-management committees; • Intervene in private territories, co-responsibility; • Create easement regimes; • Develop new forms of collaborative organization; • Foster cooperation at landscape level; • Contract management separating execution from evaluation and inspection; • Foster interministerial coordination/dialogue for biodiversity. *Research* • Impact of land use on biodiversity; • Improve the health and resilience of forests, removal of exotic species; • Establish data-sharing mechanisms between companies.

The Portuguese case study, focused on analysing the legislative, social, and economic constraints of implementing the EU Biodiversity Strategy, will provide a detailed examination of the complex decision-making process. Opening interinstitutional dialogue and prompting cross-pollination is fundamental to identifying necessary changes, inspiring action and prompting compromise between public and private organisations.

Participants of the Think Tank meetings and informative sessions demonstrated a strong collective will to improve natural resources management and implement effective spatial planning instruments for ecological connectivity. Participants expressed a keen desire to actively engage in developing solutions to reverse biodiversity loss and support healthy, resilient ecosystems. This commitment from various actors underscores the importance of collaborative efforts in achieving long-term environmental goals and reassures the need to find mechanisms of collective action and shared responsibility.

The case study will test methodologies for multilevel stakeholder engagement, from which recommendations will be drawn. The structure and delivery of informative and capacity-

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building workshops, aimed at enhancing the effectiveness of TEN-N implementation at local, regional, and national levels, can serve as a model for other case studies, as well as to other EU regions and Member States.

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6. Doñana case study

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6.1. Background

Doñana's case study is located in the southwestern region of the European continent, involving mainly the Spanish provinces of Huelva, but also part of the provinces of Seville and Cadiz, in the region of Andalucia. It borders to the north with the province of Badajoz (in Extremadura) and to the west with southern Portugal (Fig. 1). Its privileged geographical location between the European and African continents, and its transitional characteristics between the fluvial systems of the Guadiana, Tinto, Odiel, Guadiamar, and Guadalquivir rivers and the Atlantic Ocean provides to the area a high level of spatio-temporal heterogeneity, which translates into a valuable diversity of ecosystems and species. It is a key place for the wintering or transit of a large number of species of birds, fish, and cetaceans, among others, and home to some endangered species.

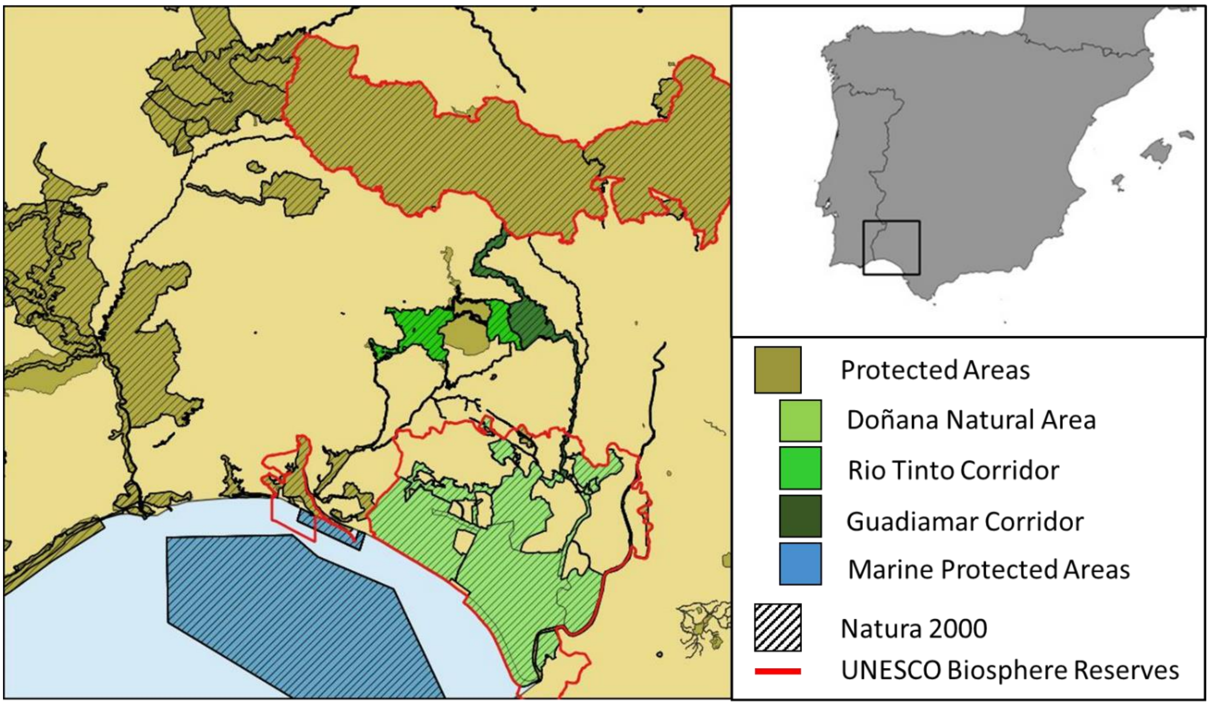

Figure 1. Location of the Doñana Case Study (black square) in southwestern Europe and distribution of protected areas within the Case Study.

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The heterogeneity of the area and its related ecological value has resulted in the establishment of multiple protected areas in the region, with varying degrees of connection, covering around 31% and 40% of the Terrestrial and Marine environments within the study area, respectively. These protected areas include one National Park, five Natural Parks, nine Nature Places, nine Nature Reserves, 10 Natural Monuments, six Peri-urban parks, two Protected landscape, two Ramsar sites, and two Marine Protected Area (OSPAR), most of which are also designated Natura 2000 sites (Fig. 1). It also includes three UNESCO Biosphere reserves.

Among the protected areas within the case study, we must highlight the Doñana Natural Area (which includes the National and Natural parks of the same name) and stands out for its great ecological value and biodiversity, giving name to the case study and in which this case study focuses especially. It is also worth to highlight the presence of the Tinto River Corridor and the Guadiamar River Corridor, which are two protected areas which act as ecological corridors facilitating species dispersal and joining the coastal areas with more interior habitats in the mountains (Fig. 1).

6.2. Identification of conservation planning challenges

The region of Doñana remains as one of the most important European conservation areas for migratory birds and endangered species and for the preservation of 35 habitat types of the Habitats Directive (almost 30% of the habitats included in Spain). However, Doñana's surroundings have suffered significant historical transformations, such as urbanization, changes in river courses or the conversion of extensive marshland or forest areas into agricultural land. All this results in an area subjected to numerous pressures and conflicting interests, between conservationist and local economies, which challenge the ecological integrity of the important habitats and species found in the area. In fact, in 2023 Doñana National Park was removed from the Green List of the International Union for Conservation of Nature (IUCN) due to mismanagement of water resources in the region leading to an important deterioration of its habitats. Unfortunately, these conflicts are expected to aggravate in the future with global change, particularly due to water limitations in the area.

Therefore, increasing connectivity of the natural habitats, expanding buffer zones, and promoting green infrastructure across agricultural and peri-urban areas will be essential to mitigate biodiversity threats while transitioning towards a more sustainable economy. Yet, the complex and fragmented governance of the region and the lack of coordination among administrations make the effective implementation of the strategies and action plans already developed for the area difficult.

There is an overlap of plans and strategies that are not always sufficiently harmonized across administrative levels. The interest varies depending on and changes as we descend in the level of decision, to the point that conservation objectives might be modified or lost due to local interests or pressures. Policies across different sectors within the same administration are also not always necessarily aligned. Furthermore, the existent plans and strategies may not necessarily represent the entire variety of habitats of considerable ecological value found in the area.

6.3. Case study objectives and expected outcomes

Given the context of our case study, our main objectives are to identify the challenges that the NaturaConnect framework may find in complex planning contexts like this one and to compare fine-scale locally-informed analyses and planning to EU-level results. We also intend to promote collaboration and conversations with relevant stakeholders in order to work together on proposals for improved connectivity in the area. Through the lessons learnt about the context, background, and challenges in the area, and through the comparison of local results

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to EU-level results, the case study aims to assess and provide feedback on the application of NaturaConnect workflows and criteria for connectivity conservation in real cases. Thus, contributing to the design and implementation of a coherent network of protected areas and areas of restored connectivity at sub-national levels.

6.4. Stakeholder engagement

As mentioned before, the governance in the areas is highly fragmented and complex, involving large number of stakeholders across different authority levels, from National Spanish administration to Regional Government of Andalusia and municipalities, in addition to protected area managers, NGOs, landowners, and the private economy sector. The role and responsibilities of each stakeholder in the decision making and management of protected areas varies depending on the zone within the region, the component or aspect to be managed within the protected areas (e.g., water management vs. pine cone exploitation), and the level of protection or designation of an area.

In order to facilitate the self-organization and coordination, protected areas have Governing Boards and Boards of Trustees. These are participatory bodies in which all institutions and groups directly involved in the management of a protected area are represented. They aim to facilitate the interaction and collaboration of all different sectors and administration in order to try to agree on decisions regarding the management of protected area. In the specific case of the Doñana Natural Area, which is the main focus of our case study we have the Doñana Participation Board, which meets minimum twice per year, usually in June and December (Table 1). As seen in the list of Table 1, the Doñana Participation Board includes administrative authorities (at different levels), Park managers, NGO, Landowners, Scientists, and the private sector.

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Table 1. Stakeholders being part of the Doñana Participation Board.

Key Stakeholders identified for Doñana (Doñana Participation Board)	Interest/Engagement (from min- 0 to 5 - max)
National authorities	
Ministry for the Ecological Transition and the Demographic Challenge (MITECO)	5
National Parks Autonomous Agency (OAPN)	
Guadalquivir Hydrographic Confederation (CHG)	
Department of the Environment (SEMA)	
Department of Coast and Sea environment (DGCM)	
Regional authorities	
Regional Government of Andalusia	1-5
Council for Agriculture, Fisheries, Water and Rural Development	
Council for environment	
Andalusian Agency for water and environment.	
Council for Innovation, Science and Industry	
Council for Public Works and Transport	
Council for Tourism, Trade and Sport	
Provincial delegations of the Council for environment in	1-5
Cadiz	
Sevilla	
Huelva	
Provincial Council of	1-5
Cadiz	
Sevilla	
Huelva	
Local authorities	
Municipalities	0
Almonte	
Aznalcázar	
Bollullos Par del Condado	
Bonares	
Hinojos	
Isla Mayor	
La Puebla del Río	
Pilas	
Raciona del Condado	
Sanlúcar de Barrameda	
Villamanrique de la Condesa	
Lucena del Puerto	
Moguer	
Palos de la Frontera	
Park Managers	
Director of the Doñana Natural Area	5
Environmental Organisation	
WWF	5
Ecologistas en Accion	5
SEO-Birdlife	5
Andalusian Association of Consumers and Users	0
Doñana 21 Foundation	5
Hermandad Matriz del Rocío	0
Landowners	
EBD-CSIC	5
WWF	5
Fundacion gonzalez gordon	5
Others	1-5
Scientists	
EBD-CSIC	5
Board of Andalusian Universities	5
Private sector	
Business organisations	0
Trade unions	0
Traditional users sector	0
Farming organisations (ASAJA, COAG, UPA)	0
Andalusian Hunting Asociation	0

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6.5. Methodological approaches and preliminary results

In order to fulfill the objectives of the case study we have planned different subtasks using different methodological approaches. Here below, we describe them and provide, when already available, some preliminary results. The accomplishment of the planned subtasks will depend on the progress of the project, challenges and opportunities encountered, and availability of manpower resources. Therefore, it is likely that these plans suffer some modifications from now to the end of the project.

6.5.1. Task 1 - Identification and revision of the work and policy processes on connectivity in the area

The case study is conducting a comprehensive review of the state-of-the-art knowledge and planning in connectivity within the region. This includes, the identification of other connectivity projects and planning processes in the area. Additionally, we are planning on revising policy documents in order to gather information about the policy tools and opportunities in the region. For example, the Spanish Water Law 29/1985 defines that all Public Hydraulic Domain (including most of water bodies and courses) must have an easement zone of five meters wide, for public use, with very limited uses, since its objective is the protection of the ecosystem. These easement zone if applied could represent an opportunity for connectivity. This revision is ongoing, a large number of documents, including scientific and gray literature, and policy and planning documents, have already been identified and will be revised, time permitting, in the coming months.

In order to introduce the context of the case study, we can mention that in Spain there is the National strategic plan for Natural Heritage and Biodiversity to 2030 (approved in 2022) and which is the national implementation of the EU Biodiversity Strategy for 2030. Since Spain has already 36.6% of the total terrestrial area protected, the strategy focuses mainly on marine environments, whose protection reaches only 12.31%, in order to reach the 30% target. Moreover, the strategy focused on defining strict protection in order to achieve the 10% target and the definition will be a consensus of the proposals of the different regions (i.e., 17 autonomous communities) of Spain. The national biodiversity pledge was already submitted to the European Commission focused on marine environments and proposed nothing yet about strict protection.

Since July 2021 there is also, in Spain, the National strategy for green infrastructure and ecological connectivity and restauration. This national strategy for green infrastructure stated that the different regions of Spain (i.e., 17 autonomous communities) have until summer 2024 to present their regional strategies and propose inventories for green infrastructure. Andalusia, however, already had its Master Plan for the Improvement of Ecological Connectivity in Andalusia from 2018 (which will be further developed to fulfill the National strategy). Additionally, in the framework of the National strategy for green infrastructure and ecological connectivity and restauration, the Ministries of Ecological Transition and the Demographic Challenge are elaborating a National Plan for the Defragmentation of Transportation Infrastructures, which will be adopted in 2024.

In the specific case of the Doñana Natural Area, there are also specific planning processes. In November 2022, the Ministry for Ecological Transition and the Demographic Challenge presented the Framework of Actions for Doñana, which are a range of short- and medium-term actions (until 2027) aiming to reverse the environmental degradation of this emblematic area and recover its ecological functioning. This action plan was later (end of 2023) completed by the release of the Framework of Actions for the Sustainable Development of the Area of Influence of the Doñana Natural Area, which focuses primarily on the social and economic

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dimensions of sustainability, as an integral component inseparable of the environmental dimension.

The existence of all these planning and policy processes already adopted or being finalized from national to local levels provides valuable information about the context and background of the case study, which may be useful as feedback to the NaturaConnect Framework. However, on the other hand, it also poses a challenge, since the case study might arrive too late to significantly influence the planning processes in the area.

6.5.2. Task 2 - Mobilization of data relevant to the study of structural or functional connectivity

A key part of our work also involves identifying and mobilising data and resources relevant to the study of local structural and functional connectivity. This task includes the search, curation, and gathering of local data on species dispersal distances, movements, distributions, demographic rates, and habitat requirements, among others. It also entails finding, checking, and making decisions about the environmental variables and data more reliable and appropriate for the area.

We have already completed the mobilization of data on dispersal distances published for the Doñana area, and there is a publication in preparation to describe these data and the gaps found on it. We also have gathered and curated all data that we could access about carnivore movements in Doñana, and is now being analyzed to prepare a publication on the differences in movements across sympatric carnivore species. In addition, we are now in the process of searching, collecting, and curating data on location, distribution and/or abundances of some model species with different habitat requirement and dispersal capacities. As of now the selection of species under consideration are: Red deer (*Cervus elaphus*), Wild boar (*Sus scrofa*), Water voles (*Arvicola sapidus*), European rabbits (*Oryctolagus cuniculus*), Perez's frogs (*Pelophylax perezi*), European badgers (*Meles meles*), Lesser-spotted woodpeckers (*Dryobates minor*), Spiny-footed lizards (*Acanthodactylus erythrurus*), lesser white-toothed shrews (*Crocidura suaveolens*), Spanish festoons (*Zerynthia rumina*), Red foxes (*Vulpes vulpes*), Egyptian mongoose (*Herpestes ichneumon*), and Iberian lynx (*Lynx pardinus*). For some of these species, we are also searching and gathering information on demografic rates and species interactions. In addition, we have to collect information on habitat requirements and avoidance for most of the species under consideration.

Regarding environmental variables, we have now mobilized, checked, and compiled data on several environmental variables. For example, we have obtained GIS layers on climatic variables from CHELSA Bioclim (https://chelsa-climate.org/bioclim/), layers on Human pressures from OpenStreetMap (https://www.openstreetmap.org/) and Human Footprint from (https://sedac.ciesin.columbia.edu/data/collection/wildareas-v3), elevation data layers from 30-Meter SRTM Tile Downloader (https://dwtkns.com/srtm30m/), basic hydrographic network of surface water bodies from the Ministry for Ecological Transition and the Demographic Challenge (https://www.mapama.gob.es/ide/metadatos/srv/spa/catalog.search#/metadata/c3e023ce-f55e-42d1-8c08-8ee8e07f6be3), land cover data from CORINE Land Cover (https://land.copernicus.eu/en/products/corine-land-cover), detailed vegetation layers from the regional government of Andalusia (https://portalrediam.cica.es/descargas?path=%2F04_RECURSOS_NATURALES) and variations in flooding levels in Doñana from the Laboratory of GIS and Remote Sensing at EBD-CSIC. In order to standardize and prepare these layers for further connectivity analyses, we needed to carry out some reclassifications, resamplings, and changes in resolution, among other things.

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One of the challenges we have found within this task has been to find data of similar quality/detail across the entire region of the case study. In fact, for example, as for the environmental information, detailed vegetation data was only found for Andalusia limiting the area for which we can perform certain analyses. Regarding other types of data, such as species distribution or demographic data, the availability of these data for some species is also biased towards some areas like the Doñana Natural area. All this will result in variations of the extention of the area to which different analyses will be applied.

6.5.3. Task 3 - Assessment of current connectivity in the area

The data gathered in Task 2 is being used to assess current structural and functional connectivity in the area for different types of habitats and species. Structural connectivity metrics were calculated using *landscapemetrics* package in R (https://r-spatialecology.github.io/landscapemetrics/) for different land cover types in the area (i.e. using CORINE Land Cover 2018 at 100m resolution). The objective of these analyses was to compare structural connectivity across the land covers represented in the area, in order to evaluate which land covers are more or less fragmented. Original CORINE land covers were previously grouped in 9 classes according to their similarity as shown in Table 2. From this grouping process, we excluded completely artificial land covers (e.g., urban areas, airports or roads), burnt areas, dump and mineral extraction sites, and sea/ocean land covers.

Table 2. Classification of original CORINE land covers into nine final categories previous to structural connectivity analyses.

CORINE land covers	Grouped categories
Agro-forestry areas	Extensive agriculture
Annual crops associated with permanent crops	Extensive agriculture
Complex cultivation patterns	Extensive agriculture
Land principally occupied by agriculture, with significant areas of natural vegetation	Extensive agriculture
Olive groves	Extensive agriculture
Broad-leaved forest	Forested vegetation
Coniferous forest	Forested vegetation
Mixed forest	Forested vegetation
Natural grassland	Herbaceous vegetation
Pastures	Herbaceous vegetation
Sparsely vegetated áreas	Herbaceous vegetation
Fruit trees and berry plantations	Intensive agriculture
Non-irrigated arable land	Intensive agriculture
Permanently irrigated land	Intensive agriculture
Vineyards	Intensive agriculture

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Inland marshes	Marshland
Rice fields	Marshland
Salines	Marshland
Salt marshes	Marshland
Beaches, dunes, sands	Sandy habitats
Intertidal flats	Sandy habitats
Sclerophyllous Vegetation	Shrubland
Transitional woodland/shrub	Shrubland
Discontinuous urban fabric	Urban green areas
Green urban áreas	Urban green areas
Coastal lagoons	Water habitats
Estuaries	Water habitats
Water bodies	Water habitats
Water courses	Water habitats

The preliminary results of these analyses show that the level of structural connectivity depends on the considered land cover (Fig. 2 and 3). In general, agricultural areas (both intensive and extensive) and shrubland show the greater connectivity across the landscape as they have the largest values for patch cohesion and aggregation indexes, larger values of mean core area index, lower mean nearest neighbour distances (Fig. 2) and larger values of effective mesh size (Fig. 3). Intermediate levels of connectivity are found for forested areas and marshlands (Fig. 2 and 3). The case of marshland is rather special since shows high values of patch cohesion index, aggregation index, and mean core area index; however, it also has a high value of mean nearest neighbour distance, implying that this land cover is distributed in large patches rather isolated from each other. The connectivity of the rest of land cover categories (i.e., sandy habitats, water habitats, herbaceous vegetation, and urban green areas) appear to be lower (Fig. 2 and 3) and their representation in the area is also much smaller.

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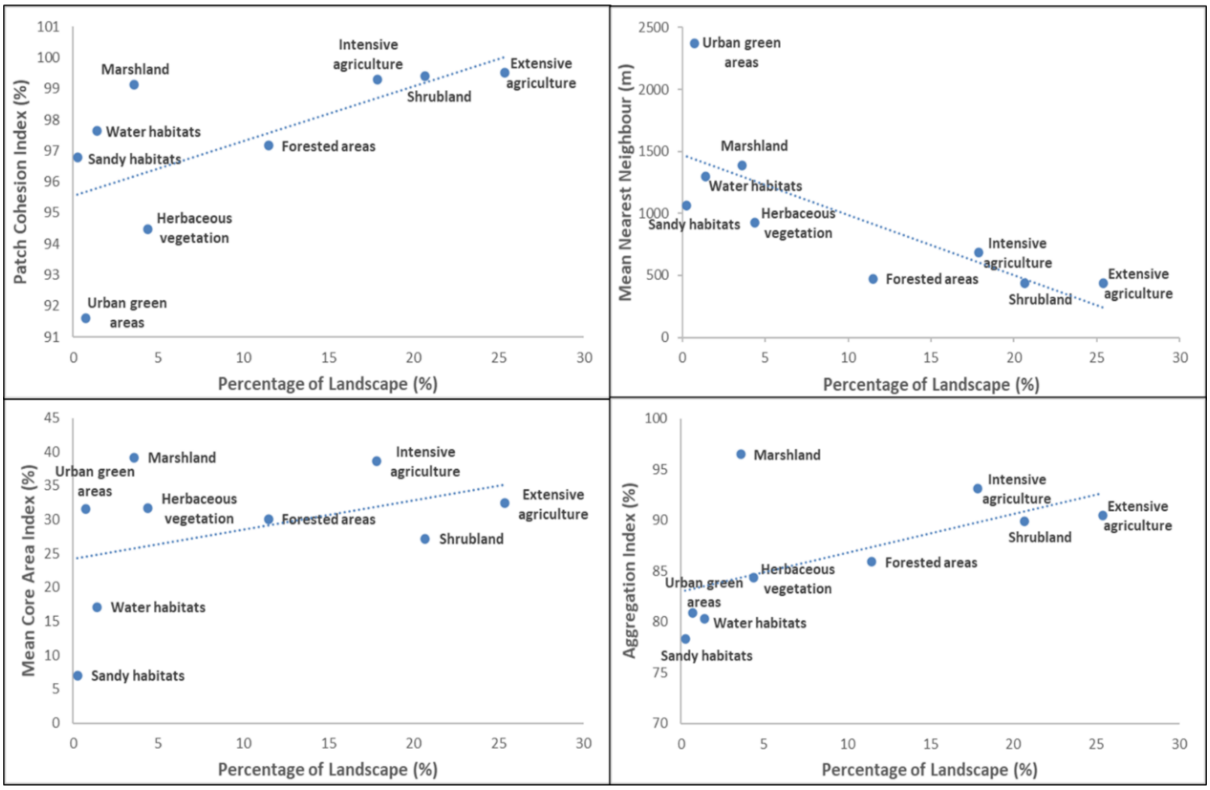

Figure 2. Value of four different landscape metrics for the nine land cover categories relative to their representation in the landscape (i.e., percentage of total landscape). The Patch Cohesion Index measures connectedness between patches and increases with higher connectedness. The mean nearest neighbor metric refers to mean distance to the closest patch for all patches in the class and describes patch isolation. The Aggregation Index equals 0 for maximally disaggregated and 100 for maximally aggregated classes. The core area index is the mean percentage of core area in relation to patch area for each patch in a class.

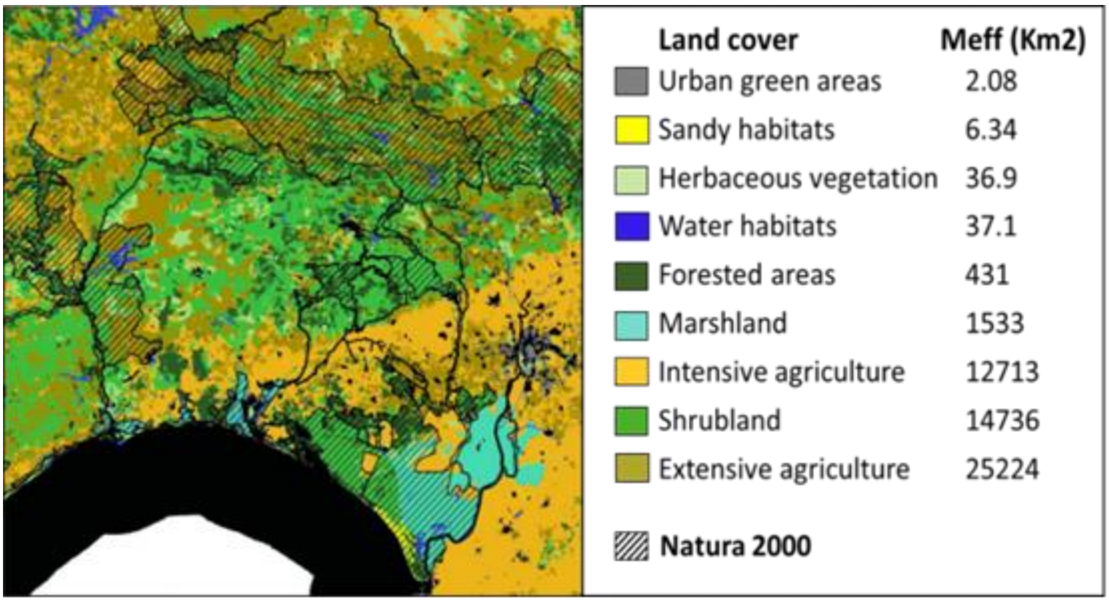

Figure 3. Representation of the Effective mesh size (Meff in Km2) for different land cover categories in the case study area. The larger the value of Meff the greater the connectivity across the given land cover category.

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When examining the exact location of the different land covers (Fig. 3), we can also observe that our focus area, the Doñana Natural Area, is mainly surrounded by agriculture (especially, intensive agriculture in orange color), explaining to a great extent the threats that the area is exposed to and emphasizing the importance of carefully interpreting structural connectivity measures.

For each land cover category, we also compared the values of the structural connectivity metrics calculated considering patches across the whole study area to the same metrics calculated only considering patches within the Natura 2000 sites. The objective of this comparison was to assess the degree to which the area among Natura 2000 sites is providing extra connectivity or not. According to our preliminary results the values of the landscape metrics per land cover category do not vary substantially when we compare only patches within Natura 2000 sites to patches across the whole area, with the exception of the mean core area index, which increases consistently for all land cover categories when we consider all patches in the study area.

With these analyses we want to emphasize the importance of accounting for different habitat and land cover types when performing structural analyses. Many studies focus on structural connectivity of forested areas; however, in areas such as the Doñana area, whose biodiversity relies on the high heterogeneity of habitats, it is essential to explore structural landscape metrics of all different land cover types to obtain a more realistic and comprehensive overview of the connectivity experience by different species depending on different habitats. For example, in the Doñana area, species depending on marshlands or dunes might be suffering connectivity limitations that are not evident when focusing on forested areas or shrubland only.

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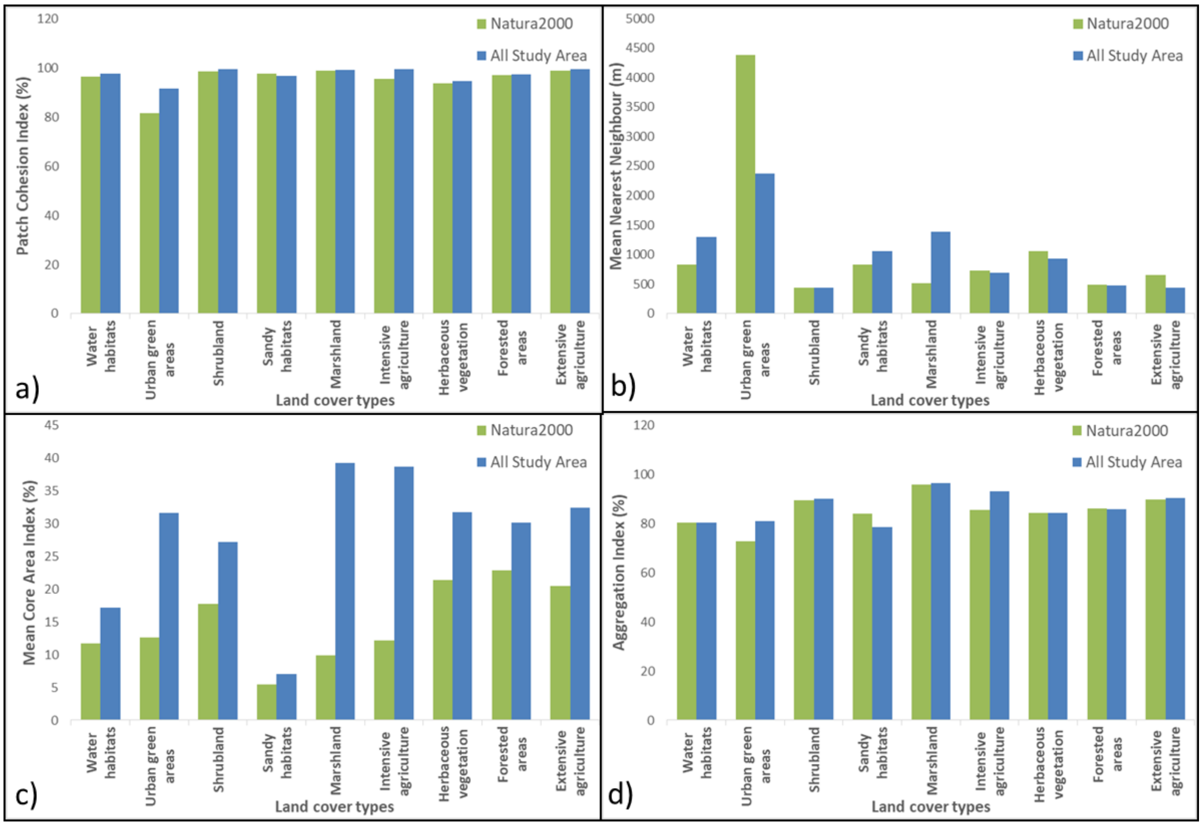

Figure 4. Comparison of structural connectivity of the nine land cover categories when considering all the study area vs. when considering only Natura 2000 sites within the area. For the definition of the landscape metrics see the caption of Figure 2.

Regarding functional connectivity, we have selected a subsample of species found in the area for which we can have enough local data to perform species distribution models. Apart from data availability, another criteria for the selection of the species was based on their habitat requirement and dispersal patterns, with the aim of having a good representation of species using the different habitat types in the area.

Among the species considered for functional connectivity analyses there is the Red deer (*Cervus elaphus*), Wild boar (*Sus scrofa*), Water voles (*Arvicola sapidus*), European rabbits (*Oryctolagus cuniculus*), Perez's frogs (*Pelophylax perezi*), European badgers (*Meles meles*), Lesser-spotted woodpeckers (*Dryobates minor*), Spiny-footed lizards (*Acanthodactylus erythrurus*), Lesser white-toothed shrews (*Crocidura suaveolens*), Spanish festoons (*Zerynthia rumina*). In each case we will use R-package Biomod2 to perform species distribution models at 100m scale. Later, we will use the circuit theory to investigate functional connectivity, although the exact type of analyses/questions may differ depending on the quality and extent of local data found for each case. For example, detailed habitat/vegetation data was only found for the region of Andalusia, so contrary to the structural connectivity analyses which cover all the area including part of southern Extremadura and eastern Portugal, functional connectivity analyses will focus on either the Doñana Natural area or on the Andalusian portion of the case study area.

For the case of Red deer and Wild boar we have investigated the effect of fences, roads, and wildlife crossings on their connectivity across the Doñana Natural Area. This resulted into the following publication accepted in 2023: *Botting, I., Ascensão, F., Navarro, L. M., Paniw, M., Tablado, Z., Román, J.,Revilla, E. & D'Amico, M. (2023). The road to success and the fences to be crossed: considering multiple infrastructure in landscape connectivity modelling. Wildlife Biology, e01187.* For the other species in the list, we are currently finishing gathering detailed

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presence absence data in order to build species distribution models, aiming at 100m resolution. These species distribution models will be later used to analyze functional connectivity for each species using circuit theory.

6.5.4. Task 4 - Dynamic modelling on effect of demographic variability and species interactions on connectivity

Focusing on species for which there is enough data on demography and movement (e.g., Iberian lynx, European rabbit or Red foxes), we are building multi-species spatially explicit demographic models (more specifically, spatially-explicit agent-based models) to investigate how demographic rates and species interactions affect functional connectivity. Functional connectivity depends on many different factors. Landscape characteristics play a large role. However, it has also been shown that demography is an important factor. Demographic rates can influence the time spent moving and the internal population dynamics of a patch influences dispersal rates. Finally, we also know that species interaction can have an effect on both population dynamics and movement decisions. This is especially true for predator/prey species.

Therefore, in the context of the Doñana case study, this project aims to expand on work already done in the Doñana area, by creating a spatially-explicit agent-based model (SEABM) of several interacting species. First, we will build a multi-species SEABM which includes the demography and interaction of a local predator-prey system (i.e., Iberian lynx and the European rabbit). This two-species SEADM may be later expanded by including other interacting species such as the Red fox or the Egyptian mongoose, which are meso-predator interaction with both the lynx, as predators, and the rabbits, as preys. As such, our three-species SEADM would include three important trophic levels and archetypes. Second, using this multi-species SEADM we will investigate the role that demography and species interactions play on functional connectivity and what role trophic level might play in this dependency.

Currently, we are finishing up the spatially-explicit agent-based model for the Iberian lynx. The model is already functioning, but movement and territorial processes being implemented in it need to be improved. In addition, we have started gathering information from existing literature to create a similar model for the European rabbit, as well as cataloging existing knowledge on the interaction between the two species that could be used to model the interaction between the two species. Finally, we are exploring the option of building simpler agent-based models to investigate the effect of variability in movement and mortality on connectivity for a range of species.

6.5.5. Task 5 - Assessment of Key Biodiversity Areas (KBAs) within the Doñana case study

The Doñana case study is also collaborating with the Key Biodiversity Areas Secretariat in order to conduct fine scale KBA scoping within the case study area. The objective is to identify and map areas within the study site which may have global significance for species conservation. The study case aims to use the results of these assessments to compare with the current network of protected areas in the region, exploring potential mismatches, as well as to support conversations and collaboration with relevant stakeholders, as it may highlight the global importance of the area. The results of this assessment may also be useful in the spatial prioritization process.

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Although still preliminary, the results of the scoping agree importantly with the location of the protected areas within the case study, especially around the Doñana National Park, which has the highest level of protection in the area, and the Doñana Natural Park surrounding it. The main mismatches between the results of the KBA assessment and the existent network of protected areas occur west of Doñana towards Portugal.

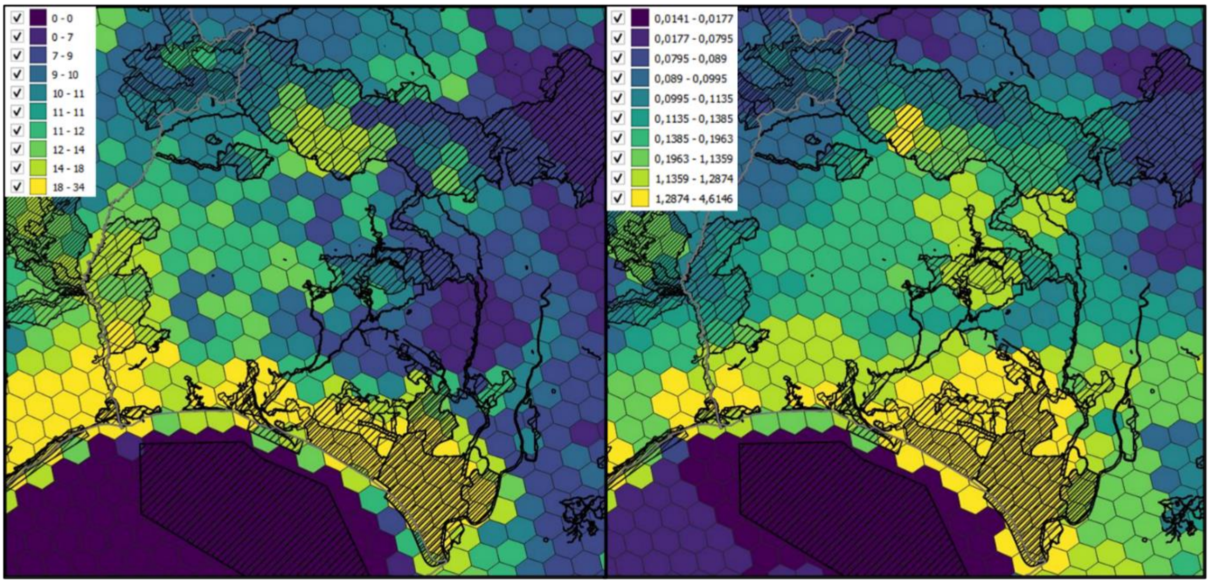

Figure 5. Systematic KBA scoping of the Doñana case study region along 50 km² hexagons. Existing protected areas in the region (including sites both within and outside the Natura 2000 network) are presented as pattern-filled polygons. Left panel presents the number of species that potentially trigger KBA Criteria per hexagon. Right panel represents Gamma irreplaceability, which measures the extent to which each hexagon is essential in order to achieve desired conservation targets for all features (e.g., species, habitats, ecosystem services). The integer component indicates the number of features for which the site is essential (irreplaceable), while the decimal component indicates how close the site is to being irreplaceable for at least one more feature.

6.5.6. Task 6 - Facilitate dialogue with relevant stakeholders and communication events

The Doñana Biological Station (EBD-CSIC) Team is building upon long-term relationships with the local, regional and national actors. We performed a first preliminary mapping of the stakeholders focusing on our main focal area within the case study, which is the Doñana Natural Area, as seen above in Table 1. Our approach has been to inform, involve and facilitate the dialog with relevant stakeholders, including the National Spanish administration, the Regional Government of Andalusia, and municipalities within and around the Biosphere reserve. This dialogue also involves protected area managers, NGOs working in the area (e.g., WWF and Seo/Birdlife), and representatives from the private economy sector, such as farming associations.

The project was presented for the first time to the stakeholders during a meeting in December 2022. One year later, in December 2023, a workshop with relevant stakeholders was organized by the EBD-CSIC team, together with the project partners BirdLife, IEEP and Rewilding Europe from WP2. The workshop brought together the Ministry for Ecological Transition and Demographic Challenge (MITECO), the Guadalquivir's Hydrographic Confederation, the General Directorate of the Network of Natural Protected Areas of Andalusia, Park Managers of the Doñana Natural Area, WWF, SEO BirdLife, and a farmer association. Together, the stakeholders identified challenges to the implementation of a coherent nature network in the area and suggested potential solutions for some of those

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challenges. The workshop, whose results are summarized in a policy brief written by WP2 in collaboration with the EBD-CSIC team and are now being revised by stakeholders, provided a great overview of the complexity of implementing strategic conservation policies and plans in real cases. This will be the main challenge of translating NaturaConnect results into real case management and conservation actions.

The case study has also established links to other projects and planning processes dealing with connectivity and barriers at different scales, which potentially affect the case study. These include: “Transportation infrastructures in anthropized environments and their impact on biodiversity conservation” and the “National Plan for the Defragmentation of Linear Transportation Infrastructures" of the Spanish Ministry of Transport, the “Spanish National Strategy for Green Infrastructure and Ecological Connectivity and Restoration”, and the “Master Plan for the Improvement of Ecological Connectivity in Andalusia" of the Regional Government.

The case study has also participated in one-to-one meetings with the advisor of the Regional Ministry of Environment, in charge of the connectivity planning in Andalusia and which proved to be open to explore collaborations with NaturaConnect, and the Head of Service (Natura 2000) from D.G.D. Biodiversity, in charge of the Protected area pledges for Spain.

The conversations and activities with these stakeholders included the exchange of information, data, and ideas, and will continue with the intention to find synergies, to build on each other's expertise and to establish potential collaborations. Through these activities, the case study is effectively bridging the gap between scientific research and practical application, offering valuable insights and strategies for enhancing ecological connectivity and protected area management at the sub-national level. Our aim is to use this bridging and potential collaborations to reach a consensus proposal for an improved connectivity together with relevant stakeholders. Nevertheless, as mentioned in Task 1, most planning and policy processes affecting connectivity in the area have been already adopted or are being now finalized, which reduces significantly the potential of NaturaConnect results to influence policy decisions/processes in the case study area.

The range of activities and events in which the EBD-CSIC team has participated so far to communicate about the NaturaConnect project and the Doñana case study are listed in the following table (Table 3). The first five events entailed the opportunity to interact with relevant stakeholders and other researchers, while the last five events were more directed to the general public and to students.

Table 3. Events and opportunities to interact with case-study stakeholders.

Event	Location	Date	Description
1st Participation Day in the National Plan for the Defragmentation of Linear Transport Infrastructures	Madrid, Spain	28/10/2022	Presentation to other researchers and stakeholders
3rd Participation Day in the National Plan for the Defragmentation of Linear Transport Infrastructures	Madrid, Spain	09/03/2023	Presentation to other researchers and stakeholders
Conference: Ecological Restoration and transport routes, jointly organised by the Ministry for Ecological Transition and the Demographic Challenge and the European projects LIFE LynxConnect and LIFE Safe-Crossing)	Sevilla, Spain	From 31/05 to 02/06/2023	Presentation to other researchers and stakeholders

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Meeting of the Doñana Natural Space Participation Council	Doñana, Spain	14/12/2022	Presentation to Donana Case study stakeholders
Workshop with WP2 and Donana Case study stakeholders	Sevilla, Spain	01/12/2023	Discussions with Donana Case study stakeholders about challenges to connectivity in the area
Project presentation to Turing Scheme students	Sevilla, Spain	25/01/2024	Presentation to Collage Students
Press release of project	Spain	15/12/2022	Press release
Press release of publication	Spain	19/01/2024	Press release
Interview at Canal Sur Radio	Spain	22/01/2024	Interview at Canal Sur Radio
Interview at Onda Local de Andalucia	Spain	24/01/2024	Interview at Onda Local de Andalucia Radio

6.5.7. Task 7 - Integration of locally-informed findings and comparison to EU-level results

In the longer-term we would like to integrate our connectivity mappings with policy mechanisms to develop together with relevant stakeholders spatial planning scenarios that will further connect the Doñana area towards other protected areas in the north of Andalusia and east of Portugal and will be representative of the habitat heterogeneity found in the area. We believe that using local data and knowledge, and, in some cases, even locally adapted analyses and approaches is important to truly involve and engage stakeholders at subnational levels. Therefore, one key aspect of our work will consist in comparing fine-scale locally-informed connectivity maps, planning, lessons learnt, and challenges resulting from our previous tasks to results from the NaturaConnect framework at the EU-level. In this way, we aim to assess and provide feedback on the application of the NaturaConnect framework to real cases at sub-national level and contribute to the design and implementation of a coherent network of protected areas and areas of restored connectivity.

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7. Leipzig-Halle case study

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7.1. Identification of conservation planning challenges

The Leipzig-Halle conurbation is a poly-central urban region in Germany with an industrial past and urban sprawl interspersed with unique wetlands and floodplain forests and diverse drier urban secondary nature areas, including large brownfield sites (Fig. 1). Connectivity along various urban-rural corridors plays a crucial role in maintaining biodiversity within urban wetlands and floodplains, as well as in more developed urban areas. It supports nature-based adaptation strategies to combat rising temperatures and heatwaves, benefiting both human and ecological health. Additionally, it fosters the creation of new species hotspots in areas with high concentrations of human populations and built environments. This peri-urban case region spans over two Federal States, which challenges cross-border cooperation across a broad network of multi-actor governance and policy instruments. Against this background, the major challenges for conservation in the case region is an enhanced dialogue with existing stakeholder networks across urban to peri-urban areas and between Federal states. This refers in particular to the riparian forests and species-rich wet meadows of and between the two core cities and their peri-urban spaces with integrated wetlands such as the Green Ring Leipzig, the Landscape Protection Area of the “Leipzig Floodplains” and the Natura 2000 network.

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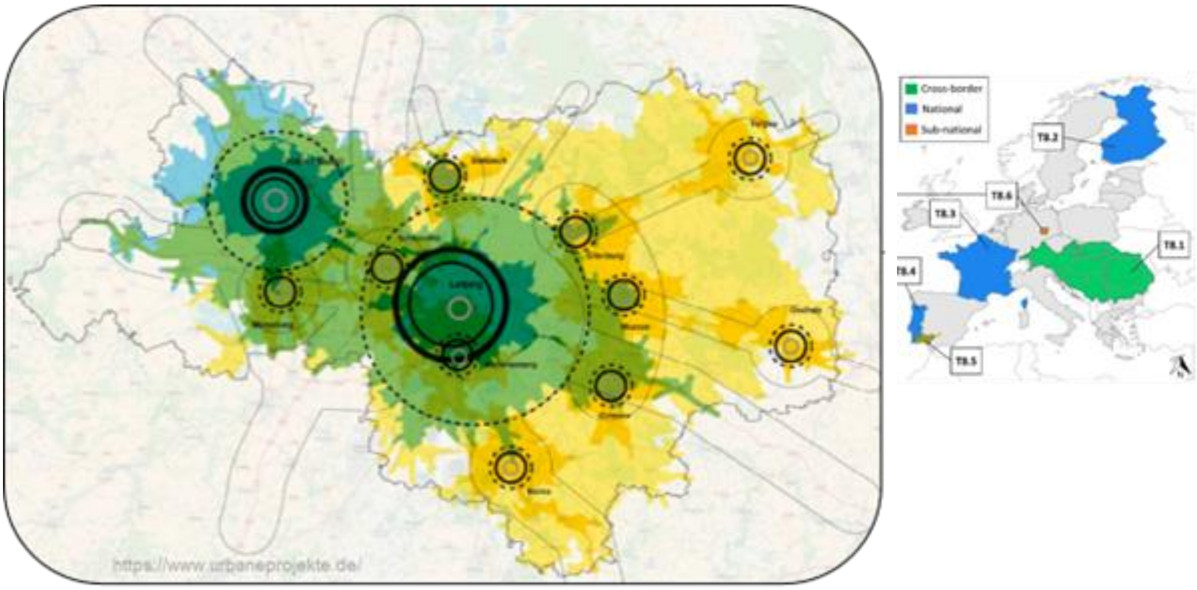

Figure 1. Location and form of the Leipzig-Halle case study. The map schema illustrates the two major centers Halle and Leipzig with their influence zone (green), urban subcenters and their zone of influence for rural areas (yellow), and development corridors relevant for connecting the region.

7.2. Case study objectives and expected outcomes

The Leipzig-Halle peri-urban floodplains case study involves a broad network of multi-actor governance and policy instruments to show how connectivity can contribute to biodiversity maintenance and multi-functional use in a peri-urban and wetland area between the cities of Halle and Leipzig. A dialogue with stakeholders will particularly focus on the contribution of existing governance structures and bottom-up citizen-supported projects, green and blue infrastructure to the Trans-European Nature Network (TEN-N), thus considering connectivity in urbanised regions under climate change.

We engage with relevant stakeholders for interactive workshops, exchange of knowledge, data and experience, and feedback on draft NaturaConnect deliverables. NaturaConnect provides and will provide tools for functional planning of ecological and social connectivity and outline funding opportunities for regional, municipal and federal (possibly national) administrations. The project will also provide an online capacity building platform to support successful implementation of TEN-N on the ground.

Expected outcomes include an evaluation of existing nature conservation concepts for wetlands/floodplain forests and river landscapes integrated into the master plans of Leipzig and Halle (INSEK and ISEK), the city's "Tree-strong City" project and the "VielFalterProject" initiated by BUND Germany and supported by iDiv, among others, as well as new indicators and financing schemes to better connect many of the existing small-scale nature conservation/protection projects, ranging from pollinator-friendly community gardens and flower strips in parks, including mowing systems, to street tree planting and afforestation of brownfields, These range from pollinator-friendly community gardens and flower strips in public parks, including their mowing management systems, to street tree planting and reforestation of brownfield sites that need to respond to heat and drought due to climate change.

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The work of the Leipzig-Halle case study is linked to issues of green planning and governance and the contribution of green-blue structures to the provision of ecosystem services. On the other hand, the case study contributes to new views on nature conservation research and nature conservation potential in large urban regions, in order to improve and complement national efforts to prepare their pledge for the targets of the EU Biodiversity Strategy. Through this case study in the NaturaConnect project, we will continue and deepen qualitative and quantitative knowledge on the extent, trends, connectivity and qualities of green spaces, particularly wetlands, including the collection and compilation of new data to support the identification of key biodiversity areas and issues.

Through this case study, NaturaConnect supports and enforces the dialogue with existing stakeholder networks, in particular focusing on the contribution to TEN-N of both existing planning structures and bottom-up citizen-supported projects on green and blue space connectivity. The starting point for this is to establish synergies with the Master Plans of the two core cities Leipzig (INSEK 2030) and Halle (ISEK 2025) both aiming at planning open and green spaces in the cities and their periphery. We will support these plans through assessing green infrastructure that contributes to both ecological and social connectivity. The green and blue infrastructures involved in this case study are the riparian forests and species-rich wet meadows of and between two core cities and their peri-urban areas with integrated wetlands, such as the Green Ring Leipzig, the Landscape Protection Area of the "Leipzig Floodplains", the Integrated Urban Development Programme INSEK and the Natura 2000 areas. Ecosystem services and connectivity studies, diversity indicators, but also a review of existing policy documents, grey literature and current funding schemes, among others, will enable a prioritisation of (functional and social) connectivity measures as a template for urbanised regions in Europe and their implementation as nature-based solutions in cities under climate change.

The core objectives are a) to support policy decisions and instruments for showing how connectivity can contribute to biodiversity maintenance and multi-functional (land) use, b) to support and enforce the dialog with existing stakeholder networks, supporting existing planning structures and bottom-up citizen-based projects on green and blue space connectivity, and c) a revisited science-policy take on green-blue connectivity. By upscaling the city-centric Master Plans to the whole region we will foster the regional interconnection of protected areas and Green and Blue Infrastructure across intensively managed ecosystems.

In addition, ***specific objectives*** accompany the assessment and communication strategy in this case study region by fostering recreational benefits as well as biodiversity enhancement in a socio-environmental just and climate resistant manner.

At the operational level, the following specific objectives have been agreed:

- Develop and apply decision-support tools to assess the performance of area-based conservation measures based on exploration and showcasing patches relevant for connectivity;
- Provide innovative indicators for supporting spatial planning and stimulate the establishment of new protected areas and corridors;
- Demonstrate in urban case studies how the strategic plan can be implemented at different spatial scales in the urban space (local scale) and between the two cities of Leipzig and Halle (regional scale);
- Elaborate different forms for connectivity of different green and green-blue patches/infrastructures and their synergies by particularly focusing on the role of floodplains/forests (green-blue connectivity), public green spaces (socio-ecological

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connectivity including human walkability), as well as revitalized brownfields and allotment gardens (functional connectivity).

- At the strategic level, the following specific objectives have been agreed:
- Support strategic and evidence-based decisions by authorities for implementing the TEN-N (in close collaboration to other WPs in Natura Connect);
- Propose a biodiversity and ES monitoring system building on principles of connectivity (in connection with EuropaBON);
- Provide a framework for capacity building that allows to learn from successful and failed projects and strategies to enhance different forms of connectivity;
- Reflect on the roles of different stakeholders and their policies or NGO activities in connectivity management at local to regional but also national to supranational scales.

7.3. Stakeholder engagement

Our urban showcase involves a broad network of multi-actor governance and policy instruments to demonstrate how connectivity can contribute to the conservation of biodiversity in both the urban wetlands and floodplains and the more urban/built and post-industrial structures, to nature-led adaptation to higher temperatures and heat waves to save the health/diversity of people and nature, and finally to support the creation of novel species hotspots (stepping stones and "connectivities") under conditions of steady population growth and pressure from the built environment.

The key stakeholders with whom the case study has established working relationships to support the above case study objectives are from the city administration, local scientific institutions and environmental NGOs.

At the beginning of the project, two informative expert interviews were conducted with representatives of national and municipal environmental protection administrations, including the Federal Agency for Nature Conservation (BfN) and the Association of German Municipalities for Biodiversity Protection (Kombio). The aim of the expert interviews is to obtain information on the current status of nature conservation measures and nature connectivity in the Leipzig metropolitan region and to explore the challenges and opportunities for the case study region from the perspective of the administration at national and municipal level. Exploring the data needs and constraints resulting from institutional barriers or knowledge and awareness gaps at different administrative levels is an important step in developing a strategic plan to support authorities in implementing TEN-N.

Qualitative semi-structured interviews were conducted with local stakeholders in the study area. The interviewees included actors from the city administration, local scientific institutions and environmental NGOs, all involved in initiatives to promote green infrastructure in the case study region. The municipality is responsible for managing urban infrastructure, planning urban development and enforcing regulations and laws. NGOs are committed to specific social, political or environmental goals. In the context of nature conservation and environmental protection, they work to preserve and protect the environment through initiatives or campaigns. In order to find current projects in Leipzig, a systematic online search was carried out using the terms 'nature conservation project Leipzig' and 'environmental protection project Leipzig'. The search did not yield any direct hits, but the homepages of several environmental organisations (BUND Leipzig, NABU Leipzig and Ökolöwe) and the

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website of the City of Leipzig's Office for Environmental Protection were displayed. These were then checked for ongoing projects. In addition, the websites of the UFZ, the German Centre for Integrative Biodiversity Research (iDiv) and the Federal Agency for Nature Conservation (BfN) were searched for suitable projects.

Table 1. Interview partners in the Leipzig-Halle case study.

Projekte	ID	Akteursgruppe	Inhalt
Gründachförderung	V1	Stadtverwaltung	Förderung von Planung, Material, Bau und Fertigstellungspflege von Gründächern innerhalb Leipzigs
Programm Zukunft Stadtgrün	V2	Stadtverwaltung	Maßnahmen zur Erhaltung ökologischer und stadtklimatischer Bedeutung der öffentlichen Grün- und Freiflächen
Stadtgrün Wertschätzen II	V3	Stadtverwaltung	Untersuchung der Auswirkungen verschiedener Begrünungsszenarien mit Fokus auf Stadtbäumen, Dach- und Fassadenbegrünungen mithilfe eines Stadtklimamodells
Leipziger BlauGrün	F4	Wissenschaft	Entlastung des zentralen Abwassersystems, der Verbesserung der Energieeffizienz und des Mikroklimas sowie Entwicklung eines klimaresilienten Starkregenmanagements
Lebendige Wände	F5	Wissenschaft	Untersuchung der die Potenziale von Fassadenbegrünungen als Klimaanpassungsmaßnahme
VielFalterGarten	F6	Wissenschaft	Schutz von Schmetterlingen durch schmetterlingsgerechte Gärten, Balkons und Stadtparks in Leipzig
Lebendige Friedhöfe	N7	NRO	naturnahe Gestaltung und Artenschutzmaßnahmen in Leipziger Friedhofsanlagen
MeinBiotop	N8	NRO	Erklärung von Maßnahmen zur Förderung der biologischen Vielfalt auf unterschiedlichen Flächen
Kletterfix	N9	NRO	Erklärung der Vorteile von Fassadengrün und Beratung zu Begrünungsvorhaben, die das Wohn- und Stadtklima verbessern
Grüne Höfe	N10	NRO	Anregung und Beratung für eine langfristige ökologische Gestaltung von Höfen und Grünflächen in Wohngebieten

The aim of the interviews was to explore the local context of the case study. The questions aimed to explore the different objectives and approaches of the actors, to explore the access to knowledge and expertise for the implementation of their projects, to assess whether the interviewed local actors have the possibility to exert political influence on the implementation of green infrastructure planning and design, what are the financial resources of the different actors and what are other barriers and/or constraints to their work. The interviews also explored the target audience, i.e., the local civil society actors that the institutions interviewed were trying to reach for participation and dissemination. The qualitative, semi-structured interviews with local actors/stakeholders will gather the necessary information from the local level, which is influenced by national and municipal administrative policies, as well as the strategies, objectives and limitations of local civil society actors. Based on WP2, the results of the barrier analysis showed valuable results for the further development of the strategic planning and implementation of TEN-N.

The results of the interviews show the similarities and differences between stakeholders from local government, scientific institutions and environmental NGOs. Most of the stakeholders interviewed identified resource-related or political/institutional barriers as important. Administrative barriers are particularly important for scientific institutions and NGOs. Among the institutional barriers, complicated application procedures are among the constraints for almost all scientific and NGO actors, but not for the administrative actors, while laws and regulations, political barriers, were important barriers for the administrative and scientific actors, but not very important for the NGO representatives interviewed. An interesting result of the interviews was that financial resources were not as much of a barrier as the lack of

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skilled workers. These and other findings from the interviews show the heterogeneity of local stakeholders, which needs to be considered in strategic planning and implementation at the local level. The knowledge gained from the interviews will serve as further input for decision support tools for green infrastructure and protected area development.

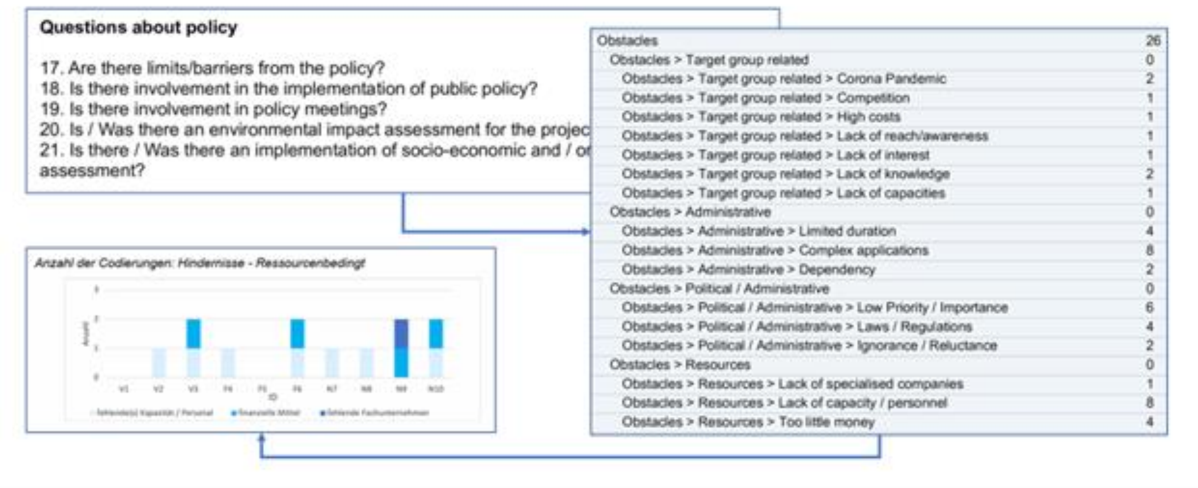

Figure 2. Data elicitation, processing and analysis using MaxQDA based on interviews with partners in the Leipzig-Halle case study.

A stakeholder engagement workshop on "Managing urban trees as a nature-based solution" was held in Leipzig, Germany, in October 2023. Challenges and future perspectives of urban trees as well as success factors in planning and management were discussed with stakeholders from planning, science and local initiatives. The strengths and weaknesses of digital tools were also discussed. Many knowledge and information gaps were identified.

Table 2. Organizations participating in the workshop "Managing urban trees as a nature-based solution".

Name of organisation
ÖkoLöwe (civil society organization)
BUND Leipzig (civil society organization)
German Centre for Integrative Biodiversity Research (iDiv)
Helmholtz-Centre for Environmental Research (UFZ)
Municipal Office for Environmental Protection, Leipzig
Federal Agency for Nature Conservation (BfN)
BUND Leipzig (civil society organization)
Municipal Office for Urban Greenery and Water, Leipzig
Humboldt University Berlin

At the municipal level, for example, there are gaps in information on tree damage on private land, as private green spaces are not included in the administrative registers. There are also gaps in the monitoring of damage, e.g., the type of damage and the vitality status of trees. A gap between knowledge and action was also identified. Another challenge at local level is that

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many decision-makers are not sufficiently familiar with the issue and that existing problems are sometimes played down. With regard to the interface between local government, civil society and environmental organisations, it is emphasised that information deficits due to a lack of transparency and accessibility of data are a problem for everyone.

At the level of civil society, there is also a lack of knowledge about who is responsible for recording and repairing tree damage and how people can take action themselves. Against this background, limited opportunities for participation, for example in planning processes, are also highlighted as problematic. The increasing separation between man and nature in urban areas leads to knowledge gaps or deficits. In addition, complex and sometimes overwhelming working conditions lead to limited time resources for civic engagement. There is also a lack of knowledge about the effects of tree damage and the legal consequences. There was also a lack of awareness of tree loss, the importance of biodiversity for vulnerability to damage, and the complex process chains from tree breeding to planting and maintenance. It was also pointed out that planning authorities often lack the necessary knowledge. The importance of opportunities for participation is emphasised several times in order to strengthen civic engagement. This can be achieved, for example, through citizen science projects.

It is important to involve all sections of the urban population, e.g., by organising competitions or visiting 'unknown' places such as private gardens and courtyards to enable an exchange of experiences. It is useful to involve stakeholders and personal networks in the initiation process. In the digital space, which is often characterised by information overload, the challenge is to arouse people's interest. However, there is also a risk that too many digital tools could lead to excessive demands and promote a separation between people and nature. Education is another important element in strengthening civil society in the long term. When it comes to education, it is important to address specific target groups when imparting knowledge. This includes sharing and experiencing nature as well as pooling and disseminating knowledge. Focusing on nature and tree education also promotes understanding and appreciation of the environment. It was also emphasised that data with high spatial and temporal resolution should be made easily accessible to civil society.

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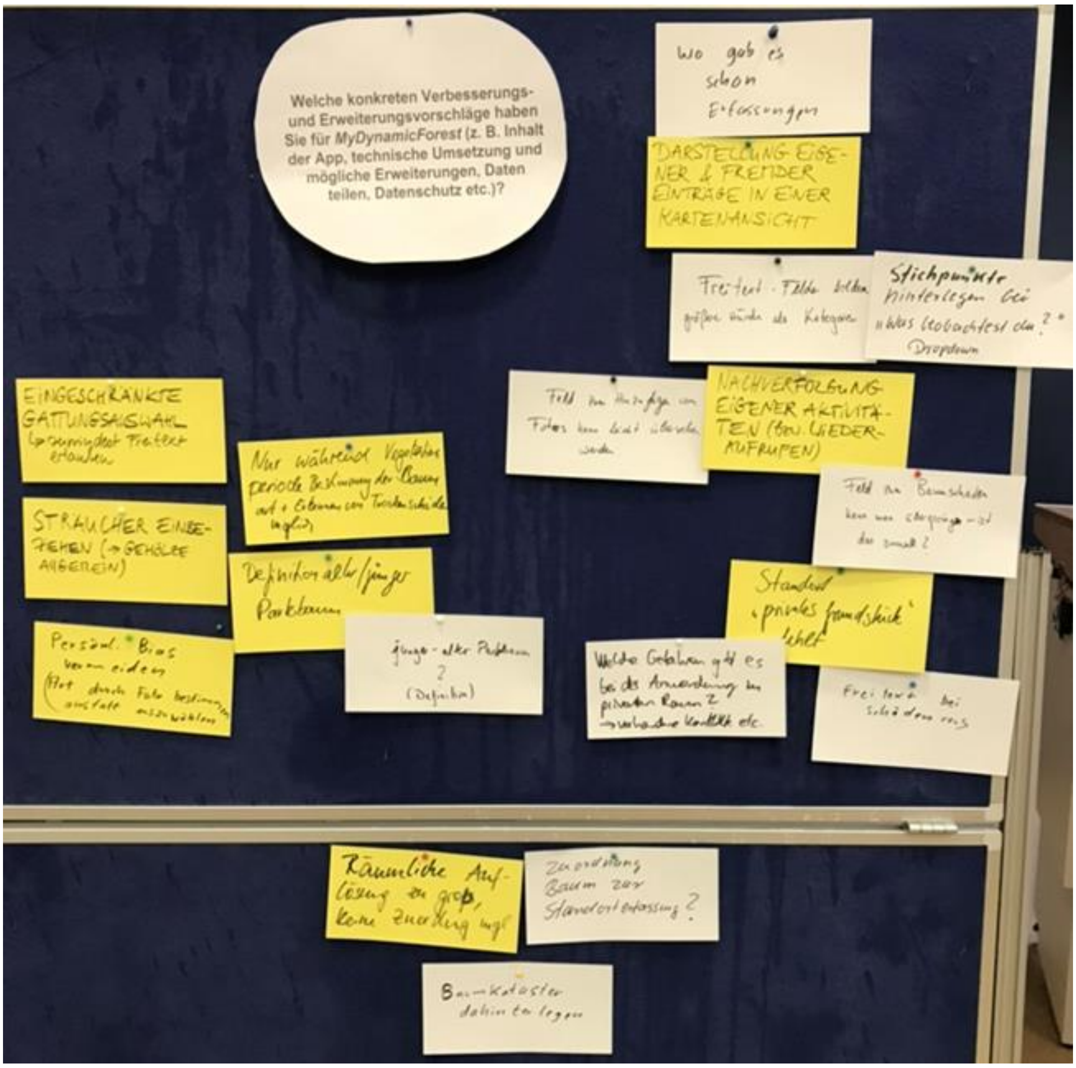

Figure 3. Ideas and questions from the stakeholders involved in the workshop "Managing urban trees as a nature-based solution" clustered on cards according to topics and categories.

7.4. Policy context

In Germany the designation of types of protected areas is legally based on the “Gesetz über Naturschutz und Landschaftspflege (Bundesnaturschutzgesetz – BNatSchG)” (federal nature protection law). The first version was enacted in the Federal Republic of Germany in 1976 replacing the “Reichsnaturschutzgesetz” (Reichs nature protection law) (RNG) from 1935 (Wikipedia: Bundesnaturschutzgesetz). In the German Democratic Republic, the RNG was replaced in 1954 by the Gesetz zur Pflege und Erhaltung der heimatlichen Natur (law for the care and conservation of the native nature) (Wikipedia: Reichsnaturschutzgesetz), and was later included in the Landeskulturgesetz (national culture law) (Wikipedia: Naturschutz in der DDR). The BNatSchG was applied to the former GDR territory after reunification. It was reformed in 2007 and again in 2020 (Wikipedia: Bundesnaturschutzgesetz). The federal law sets the guiding principles for nature conservation and the states legislation pass laws that regulate largely according to these principles with respect to the states´ special conditions and necessities, including the executive regulations for designating nature conservation areas below the national level. For the case study area of Leipzig both the federal as well as the state nature conservation law (Gesetz über Naturschutz und Landschaftspflege im Freistaat

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Sachsen (Sächsisches Naturschutzgesetz – SächsNatSchG)) contain regulations referring to the protection and conservation of nature as well as connectivity of these protected areas, as well as regulations concerning the development and protection of the Natura 2000 network. The state laws paragraphs refer to the corresponding paragraphs in the federal law. Further influence on environmental and landscape protection and nature conservation comes from the spatial planning laws of the administrative levels, the federal spatial planning law, in German: Raumordnungsgesetz (ROG) and the state spatial planning law of Saxony: in German Gesetz zur Raumordnung und Landesplanung des Freistaates Sachsen (Landesplanungsgesetz – SächsLPlG). In the ROG the principles of spatial planning state the importance of intact ecosystems and the requirement to protect and restore them. The principles also state the requirement to reduce land use and consider the requirements of ecological connectivity. The ROG also regulates the requirement and the degree of environmental assessment and monitoring in the spatial planning procedure. The SächsPlG goes into detail on the procedures and contents of the environmental assessment but does not add any stricter environmental regulation.

General objective of a national network of connected biotopes is the inclusion of 10 % of each state´s area into the biotope network (Bundesnaturschutzgesetz, 2024). Protected areas can be designated as nature reserve, national park or national nature-monument, biosphere reserve, protected landscape area, nature park, nature-monument or protected landscape component. The biotope network is explicitly expected to serve the improvement of the Natura 2000 network. Establishing connectivity is explicitly required to be done across state-borders and with long-term agreements. Linear as well as stepping-stone biotopes are required by law to connect natural biotopes such as, riparian zones across landscapes with heavy agricultural influence.

In urban areas, the demand for multiple different landscape functions leads to the inclusion of different regulatory frameworks needing to be integrated in the process of planning and conserving and developing urban green infrastructure, protected areas and connectivity. To accomplish this in the complex urban setting, the city of Leipzig has an urban development strategy that is based on the integrated urban development concept 2030 (Integriertes Stadtentwicklungskonzept (INSEK) 2030), that combines the relevant departmental plans and their essential development-specific messages (City of Leipzig – Stadtentwicklung, 2024). The department-specific plan related to urban green and blue infrastructure is the concept for open space and the environment. The INSEK´s concept for open space and the environment reflects the challenges of urban development of a growing city between green-blue and grey infrastructure development (City of Leipzig, 2018). The structure of connectivity within the city and beyond is oriented towards a ring-radial system, that aims to include the riparian zones of the urban river banks and floodplains as axis to connect green and blue infrastructure elements (ibid.).

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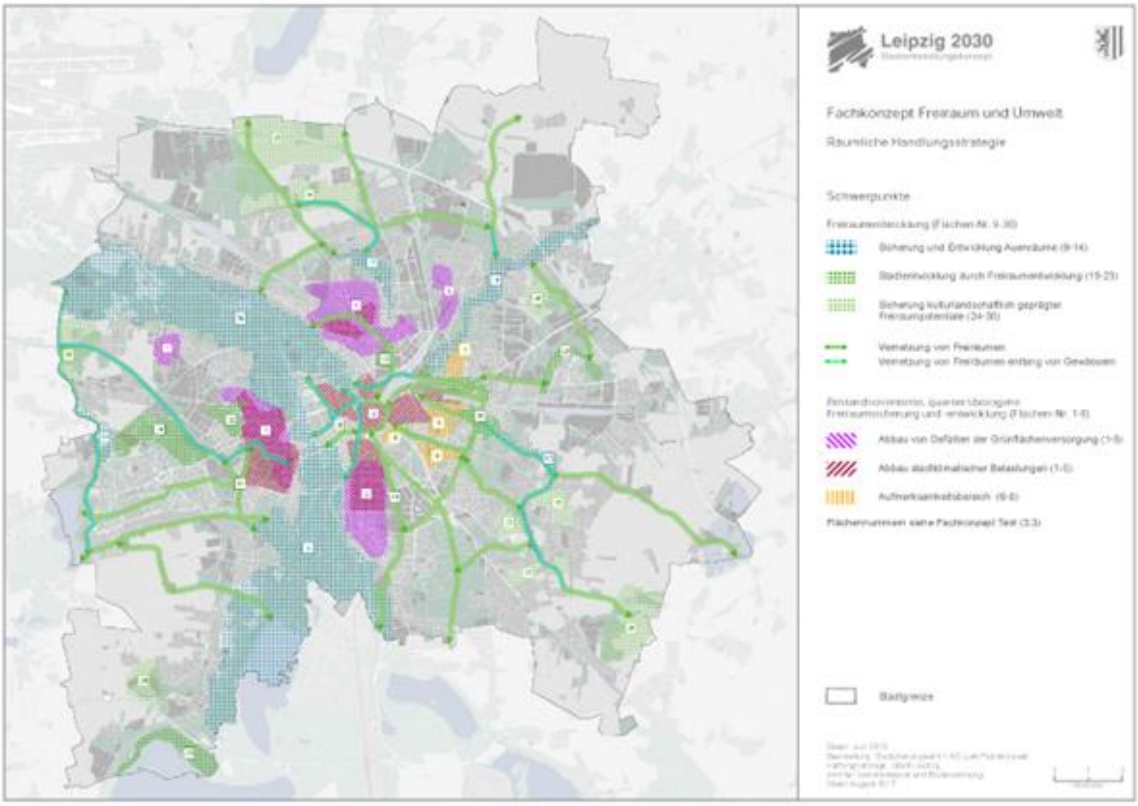

Figure 4. Schematic map illustrating strategic areas and corridors for ecological and sustainable development in the city of Leipzig based on the Integrated Urban Development Plan for Leipzig 2030 (City of Leipzig, 2018).

Another key concept of the plan is termed “Doppelte Innenentwicklung”, which can be translated into two-fold inner development and describes the idea of treating the development of grey infrastructure equal and in relation to the development of green and blue infrastructure (City of Leipzig Amt für Stadtgrün und Gewässer, 2021, p. 16). Brownfields left from the period of shrinkage following the reunification shall be developed into new greenspaces serving as recreational areas for the densely built-up inner-city quarters. Processes of proactive planning and civil society engagement are key to achieve a feeling of ownership among Leipzig´s residential population (City of Leipzig, 2018, p. C-3). However, it has to be acknowledged, that the concept for open space and the environment is only one departmental plan including eleven others, among them Housing or Economy and Employment, which can lead to conflicts, especially when different actors are involved in the procedures.

In 2021, the Masterplan “Green” Leipzig 2030 (Masterplan “Grün” Leipzig 2030) was introduced with the objective to counter unbalanced growth in favour of buildings and traffic infrastructure construction (City of Leipzig Amt für Stadtgrün und Gewässer, 2021, p 11). The masterplan was also showcased as a model-project in the urban green labs project by the Federal institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) im Bundesamt für Bauwesen und Raumordnung (BBR), 2021). The Masterplan can be interpreted as an addition to the INSEK with a special focus on the green space development, as it aims to identify the potentials for improving existing greenspaces as well as developing new ones. The planning process, started in 2017. Initiated by the City of Leipzig, Office for Urban Greenery and Waters the process of developing the masterplan was based on a broad citizen involvement including online-surveys, open meetings, city-walks and workshops for stakeholders such as allotment-

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garden associations, which increased awareness for the masterplan and its objectives (City of Leipzig Amt für Stadtgrün und Gewässer, 2021). The main topics of the masterplan are adapting to climate change, biodiversity, health, environmental justice, active mobility, and it builds on the two tasks of safeguarding green and blue infrastructure and develop and qualify green and blue infrastructure and their connectivity (City of Leipzig Amt für Stadtgrün und Gewässer, 2021, p 11). The Masterplan extends beyond the city limits of Leipzig by identifying so-called landscape development corridors (Landschaftslinien) (Fig. 5) to connect the green and blue infrastructure in the city with protected areas outside the city limits (City of Leipzig Amt für Stadtgrün und Gewässer, 2021, p.19). The corridors are a strong concept of green connectivity and extend the guiding concept of the ring-radial-structure envisioned in the INSEK 2030 by providing clear designations and development objectives.

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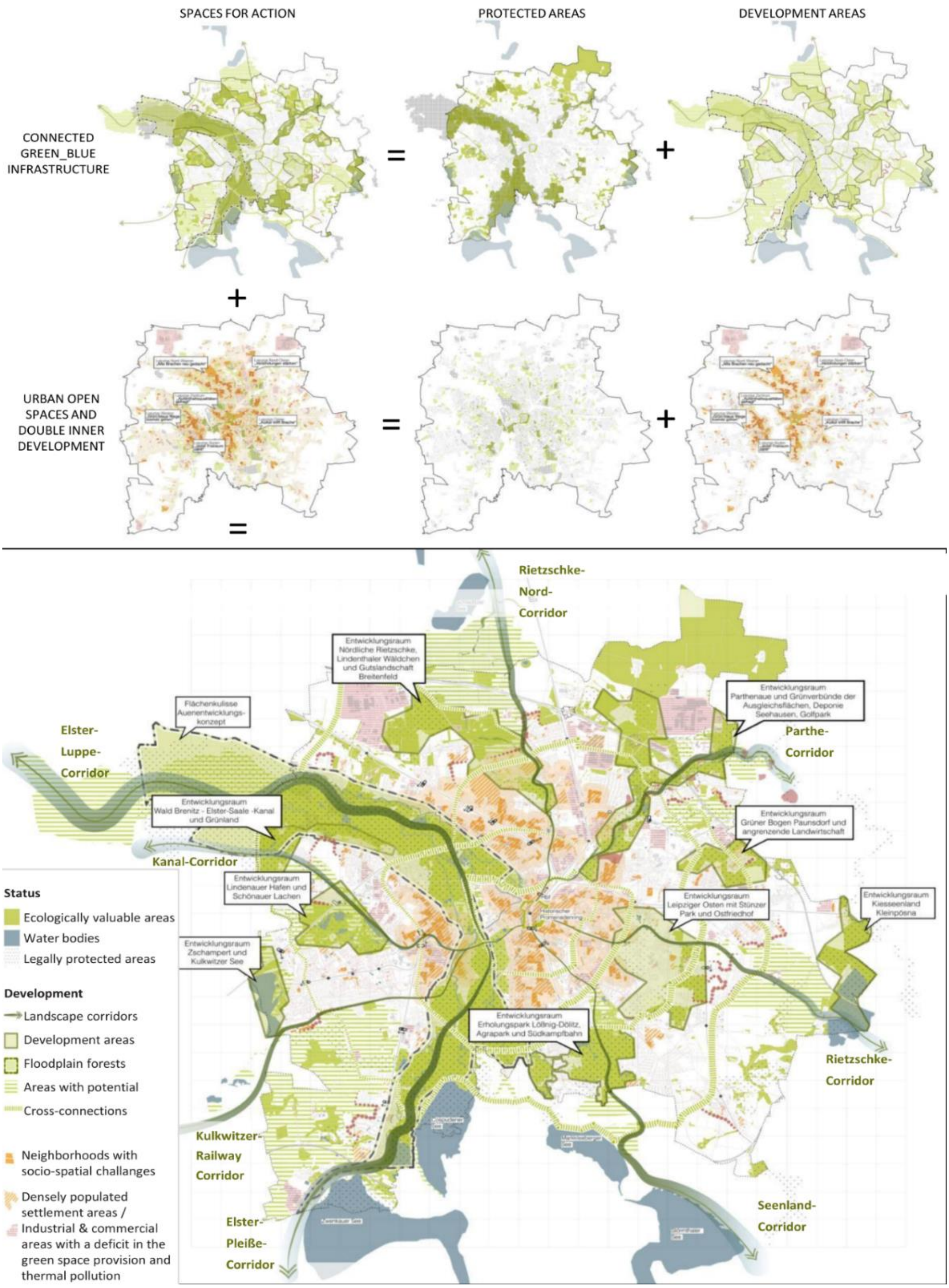

Figure 5. Development corridors and areas specified in the Masterplan Green (City of Leipzig, 2021).

Financing of local nature conservation and connectivity depends on the actors involved in the respective initiatives. Projects from the city administration are mainly financed by public money, in detail federal, state and communal funding. A notable exception is the street tree

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sponsorship initiative, which enables citizens to sponsor the planting of and care for an urban tree in the city of Leipzig. This initiative is based on donations and thus uses mainly private funding to support communal tree planting efforts (City of Leipzig Amt für Stadtgrün und Gewässer, 2024). Science institutions that are also involved in nature conservation, restoration and connectivity are financed mainly from federal as well as state funding. NGOs local nature conservation and connectivity initiatives are mainly financed by donations, with a smaller proportion of federal and communal funding, depending on their respective projects. Financial instruments that aim to leverage investment funds into ecological, or green investments play no significant role on the spatial scale of sub-regional to local nature conservation and connectivity initiatives.

7.5. Methodological approaches and preliminary results

Below, we describe the different tasks in the order of priority and chronology, i.e., the order in which they will be commenced. The final details, and potential to implement overall, of the task including quantitative analysis (Tasks 1 to 4) will depend on the process with the stakeholders and projects (including other NaturaConnect WPs) whose outputs we are dependent on. Thus, there is a relatively high probability of changes to the plans described below and not all quantitative tasks will necessarily be conducted within the scope of NaturaConnect.

7.5.1. Task 1 - Forest and green space connectivity analyses

Objective

Urban tree systems provide a range of ecosystem services (ES). Thereby, spatial aspects of heterogeneity and configuration of the socio-ecological landscape play a major role in maintaining biodiversity and ecosystem services and hence in human wellbeing. Given the heterogeneity of land use in cities, any change within the complex green infrastructure network essentially impacts the habitat connectivity of green infrastructures in cities (Bodin et al., 2007). Against this background, we ask how urban tree systems are connected and what is the potential of protected area management for enhancing their connectivity. In the following we refer to habitat connectivity defined as the probability of movement of species between all resource patches in an ecological network landscape (Egerer and Anderson, 2020). An ecological network can include core areas that are areas of high-quality habitat while stepping stones are small habitat areas that can act as corridors for the movement of species by serving as islands in between larger core areas. From a structural perspective, connectivity is the extent to which habitat patches in the landscape are linked physically (Lynch, 2019). Although being easy to understand, measure and communicate, it does not consider how species actually move through and use the landscape (Landscape Institute, 2016). In contrast, functional connectivity refers to how a network is used and includes the behaviour, mobility and ecological requirements of a particular species in that landscape (Gurrutxaga et al. 2010). Physically disconnected green spaces can be functionally connected as stepping stones with functional connectivity being very helpful to map patch connectivity and establish theoretical biological corridors ensuring the integrity and continuity of the urban ecological process (Rincón et al., 2021).

Data and methods

We used graph theory modelling to estimate the importance of individual landscape elements against their overall connectivity contribution of the ecological network (Pascual-Hortal and

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Saura, 2006). This is in particular beneficial in fragmented but complex landscapes as urban areas using network analysis (Bodin et al., 2007). We used freely available and high-resolution dataset on tree-cover-density (TCD, level of tree canopy density in a range from 0-100%), for the reference year 2018 (10-meter resolution, Copernicus, 2021). A benefit of this high resolution is the guarantee, that a pixel illustrates an old growth tree, which increases the representativeness of a real existing tree functioning as breeding habitat. The TCD data was processed using a Morphological Spatial Pattern Analysis (MSPA) using Guidos toolbox (Vogt and Riitters, 2017) segmenting each canopy pixel into seven mutual canopy categories. Out of these, the following classes have been used for the further data processing: cores, edges, islets and bridges. These classes have been used for performing the FCA by applying a minimum patch area of 0.1 ha as habitat for breeding birds (Mollashani, 2020). We used Graphab as a tool for modelling ecological networks based on graph theory by focusing on behavioural interactions of a targeted species for functional connectivity calculation (Graphab, 2022). We created planar networks as usually being applied in ecological connectivity analysis as a node within the graph only connects directly to its geographical adjacent nodes surrounding it and, consequently, must connect to more distant nodes by passing through stepping-stone nodes (Minor and Urban, 2008). The choice of dispersal distances was based on a literature review on breeding birds in urban ecosystem in which a maximum of 400m was applied (Marzluff et al., 2016).

This study uses four metrics which are based on the probabilistic connection graph model of PC allowing for continuous modulation of the connection strength or dispersal feasibility. First, for evaluation the importance of nodes and edges for the functional connectivity, this study uses the delta PC (dPC) as a powerful indicator for prioritizing landscape elements for their habitat function of urban wildlife widely used in conservation planning (Saura and Pascual-Hortal, 2007). The dPC value equals the percent decrease in PC if this element is removed and is, hence, a relative measure of the contribution of a node or an edge to the functional connectivity of the whole network (Saura, 2010). The global PC is calculated in the initial state, a patch is removed from the graph and the global metric is recalculated. The difference between the two values is implemented in the removed patch, reflecting the loss of connectivity generated if this element is removed. This calculation is then applied to each of the nodes and edges, thus making it possible to prioritize them according to their contribution to the overall connectivity. The result of the delta PC (dPC) is therefore local, but with reference to the global level. Second, in order to access why a patch is important for overall connectivity, we used the decomposed dPC which is expressed in three metrics (their sum is equal to the dPC value (Saura and Rubio, 2010):

- dPCintra: Intrapatch connectivity for a patch based on the assumption that connectivity exists within the patch and is, consequently, proportional to patch area reflecting internal characteristics.
- dPCflux: Area-weighted dispersal flow through the connections of a patch to or from all of the other patches in the landscape. It depends both on the area of a patch and on its position within the landscape.
- dPCconnector: Topological-based importance of a patch or link for maintaining connectivity between other patches as a connecting element (stepping stone) between them. A certain patch or link will contribute to dPCconnector only when it is part of the best (maximum product probability) path for dispersal between two other patches, and is independent of the size of a patch.

Finally, the results have been intersected with highly precise land use data (ATKIS, the Official Topographic-Cartographic Information System) for 2020 and with Leipzig's official cadastral information on brownfields (INKOBRA) which covers spatial data on existing brownfields, construction sites and revitalised brownfields for the years between 1998 and 2020.

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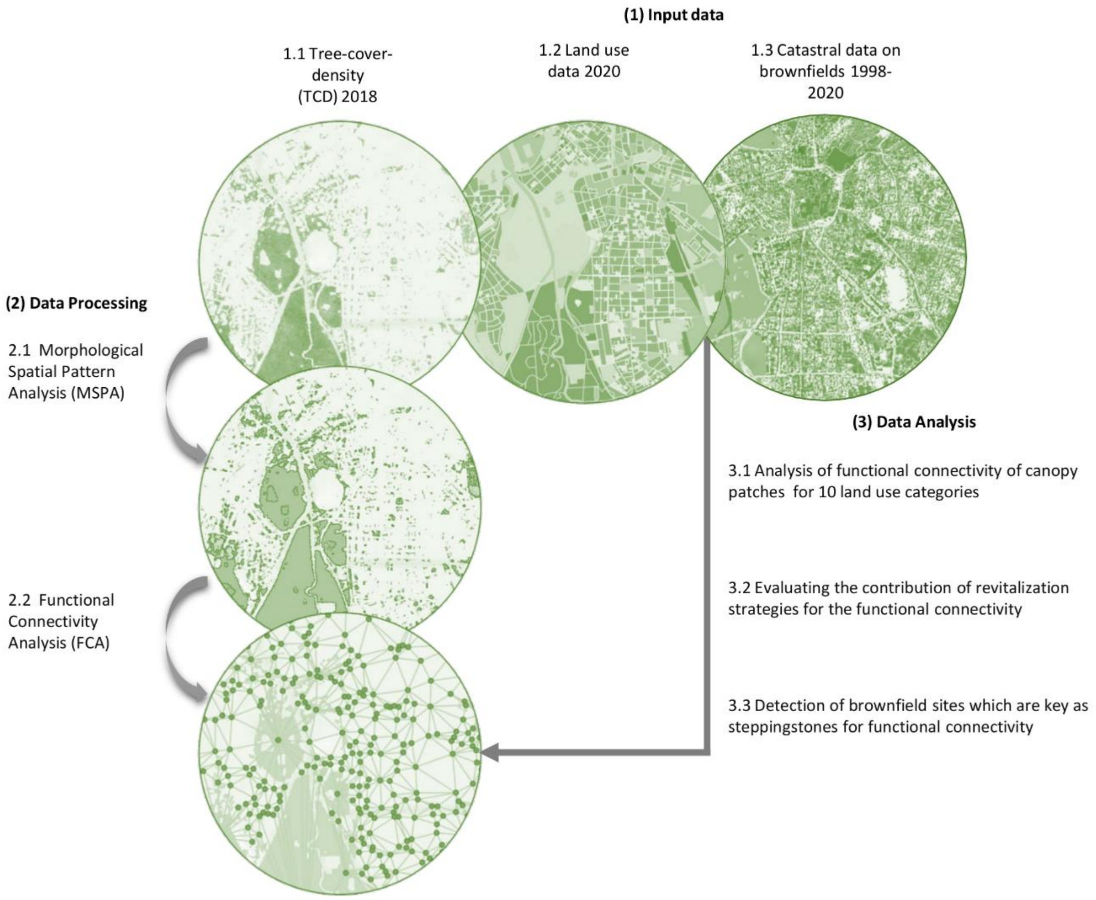

Figure 6. Workflow showing data input (step 1), data processing steps (step 2), and data analysis steps (3.1 to 3.3).

Results and short conclusions

The tree patches in Leipzig form a dense network consisting of nodes and edges as the map below displays (Fig. 7). Both network elements, nodes and edges, have a different relevance for the functional connectivity, as indicated by the dPC value. The map shows that, in particular, Leipzig's floodplains form an important functional corridor from north–west to the south. However, each tree patch contributes to the functional connectivity in a threefold way. The central floodplains and adjacent parks, such as the Clara-Zetkin park or Rosental park, facilitate the movement of species and, at the same time, serve as habitat area due to their size and quality of vegetation, as indicated by the dPCintra value (Fig. 7). Secondary networks contribute to the connectivity due to their potential for interaction with other habitat patches indicated by the dPCflux value. Examples of these networks are formed, for example, by large parks or cemeteries in the south-eastern part of the city (e.g., Südfriedhof), semi-private green spaces such as allotment gardens or green sport facilities in the north-eastern part of the city (e.g., Freibad Schönefeld), or semi-natural areas such as shrubland in particular at the inner fringe. Also, revitalised areas play a big role in connecting canopy patches with each other within the whole network. One example is the Agra Park in Leipzig's southern floodplains. The city administration aimed for the extensive renaturation of the whole former agriculture exhibition grounds. Due to its location vis-à-vis to the central floodplains, this area provides excellent connection for the large floodplain forest to tree patches within the built-up structures of the city. Finally, several tree patches play a central role as stepping stones with their immediate surrounding patches, indicated by the dPCconnect value. This refers basically to

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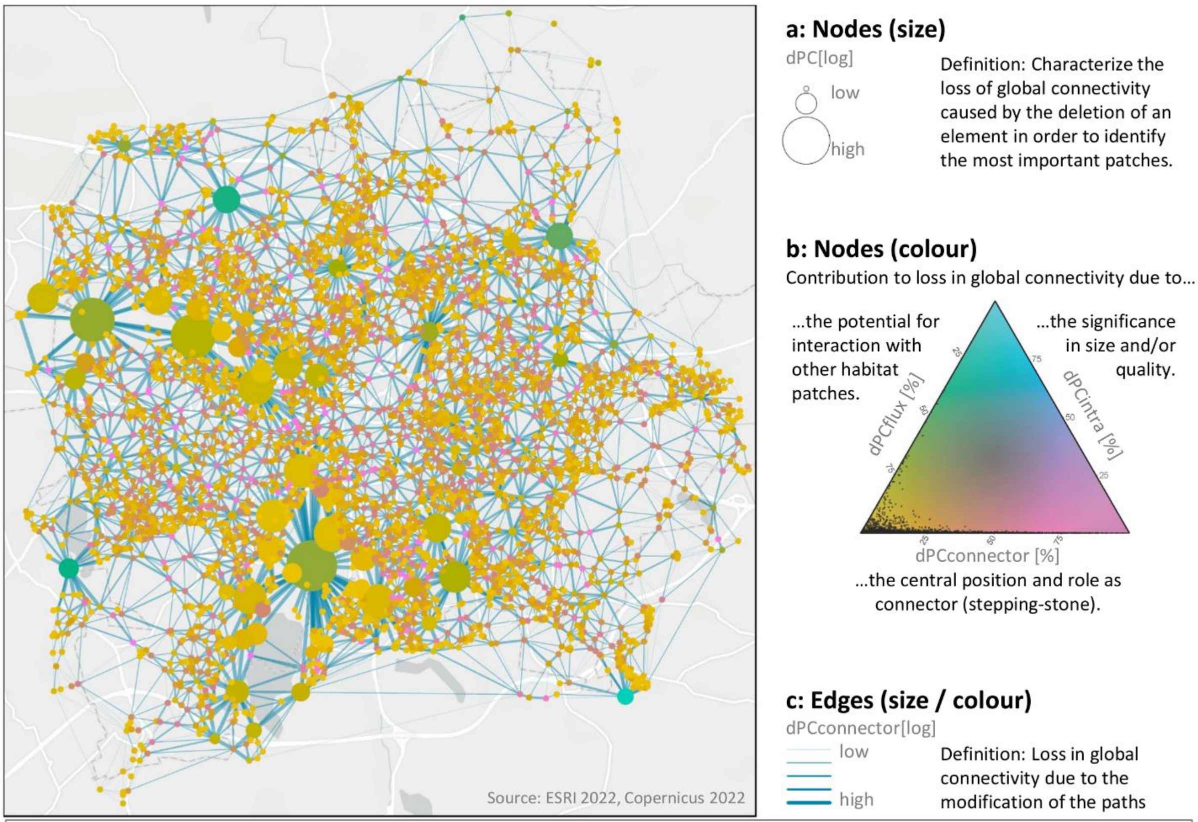
brownfield sites and private treed areas, predominantly located within the dense urban built-up structures of the city supporting a fine web of edges throughout the city and, finally, support bigger nodes in expressing their high connectivity values.



Example: A dPC value of 0.3, a dPCintra value of 0.02, a dPCflux value of 0.19 and a dPCconnector value of 0.09 indicates that if the patch disappears, the potential 30% drop of global connectivity is due to 2% of the loss of its capacity (size), 19% due to the loss of connections with neighboring patches, and to 9% to the modification of the paths.

Figure 7. Characteristic of the functional connectivity of urban tree systems (UTS) in Leipzig highlighting the overall importance of patches (a: node size), the individual contribution to this importance with respect to three fractions (b: node colour), and the relevance of individual paths (c: edge size/colour).

7.5.2. Task 2 - Green space, recreation area and accessibility analysis

Objective

With increasing pressures on urban parks and urban green-blue areas as recreational spaces, the sub- or peri-urban space offers alternative recreational possibilities. However, with accessibility analyses often focusing exclusively on cities as delineated by their administrative boundaries, such recreational opportunities, and emerging urban-rural recreational flows as a form of interaction between cities and their hinterland conceptualized as rural-urban interface, often remain understudied (Wolff et al., 2020). The rural-urban interface may however provide a holistic and integrative planning perspective through challenging stakeholders across the urban-rural divide, and by calling for collaboration of urban-municipal as well as regional actors. Conversely, neglecting the rural-urban interface may pose limitations for effectively connecting urban and rural natural and semi-natural areas, and for (prioritizing) conservation and protection while simultaneously considering recreational demands of populations at the scale of multifunctional landscapes.

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To exemplify the rural-urban interface at the level of the Leipzig-Halle conurbation against the background of recreational demands, social-ecological connectivity within this region is being assessed. Here, socio-ecological connectivity is understood as an opportunity for inhabitants to access green-blue infrastructures at broad scale, thus including green spaces, forests, blue spaces, etc. within both the urban space and the urban hinterland.

In this regard, whilst walkability is a commonly used indicator to assess accessibility to green spaces from an urban perspective, walkability may perform poorly at regional scale due to potentially underestimating green space provisioning. Therefore, here, a focus is on assessing socio-ecological connectivity based on multimodal accessibility, i.e., accessibility to green spaces through an integration of diverse modes of travel including walking, cycling, public transportation, or motorized private travel. In so-doing, the analytical focus determining access to green spaces is shifted from (intraurban) walkability based on physical to (regional-scale) cognitive distance, i.e., transport (inter-)relations and travel time cost, as relevant regional-scale green space accessibility metrics (Chen et al. 2022; Dony et al., 2015; Xu et al., in press).

Findings will uncover socio-ecological connectivity and thus accessibility to recreational spaces at regional scale and may furthermore reveal potential corridors of recreational flows. Through the consideration of multiple modes of travel, including public transportation, differences in socio-ecological connectivity grounded in mode of travel are elicited, and temporal aspects highlighted, e.g., considering varying public transport schedules and frequencies over time of day and day of week.

The analysis will inform stakeholders in various ways. First, to meet recreational demands, opportunities for improving socio-ecological connectivity may be identified. In this regard, improvements of socio-ecological connectivity may be particularly desirable for low-carbon, active modes of travel, thus promoting sustainable and climate-friendly recreational behaviours. Second, through contrasting socio-ecological connectivity with ecological connectivity at regional scale, the importance of patches under different analytical lenses will be revealed, and similarly, ecological and recreational corridors be identified. In so-doing, potential synergies or conflicting goals with respect to enhancing both ecological and socio-ecological connectivity may be uncovered.

Data and methods

The analysis will utilize and integrate various openly available spatial data (Fig. 8). Elements of the green-blue infrastructure as recreational destinations and points of interest will be derived from land-use/land-cover datasets, including OpenStreetMap or Urban Atlas. Features of the built environment, including transportation infrastructures, are obtained from OpenStreetMap, and processed to prepare a transportation (road) network. This network will subsequently allow distance and/or travel time-based modelling of accessibility based on walking, cycling, and motorized private travel.

In addition, General Transit Feed Specification (GTFS) data from regional transport providers (Mitteldeutscher Verkehrsverbund/MDV) will additionally be consumed, in order to construct a public transportation network. By considering physical (stops), relational (lines, routes, interchanges) and temporal (frequencies, schedule) network properties, this public transportation network provides all relevant information for modelling public transport (PT). Both networks are subsequently used to assess individual and integrated modes of travel. In this assessment, different travel profiles may be considered, thus allowing for the implementation of varying relational behaviours or acceptable travel time constraints, thereby

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reflecting, e.g., on elderly travellers or families with children. The assessment is conducted using r5r (Pereira et al., 2021).

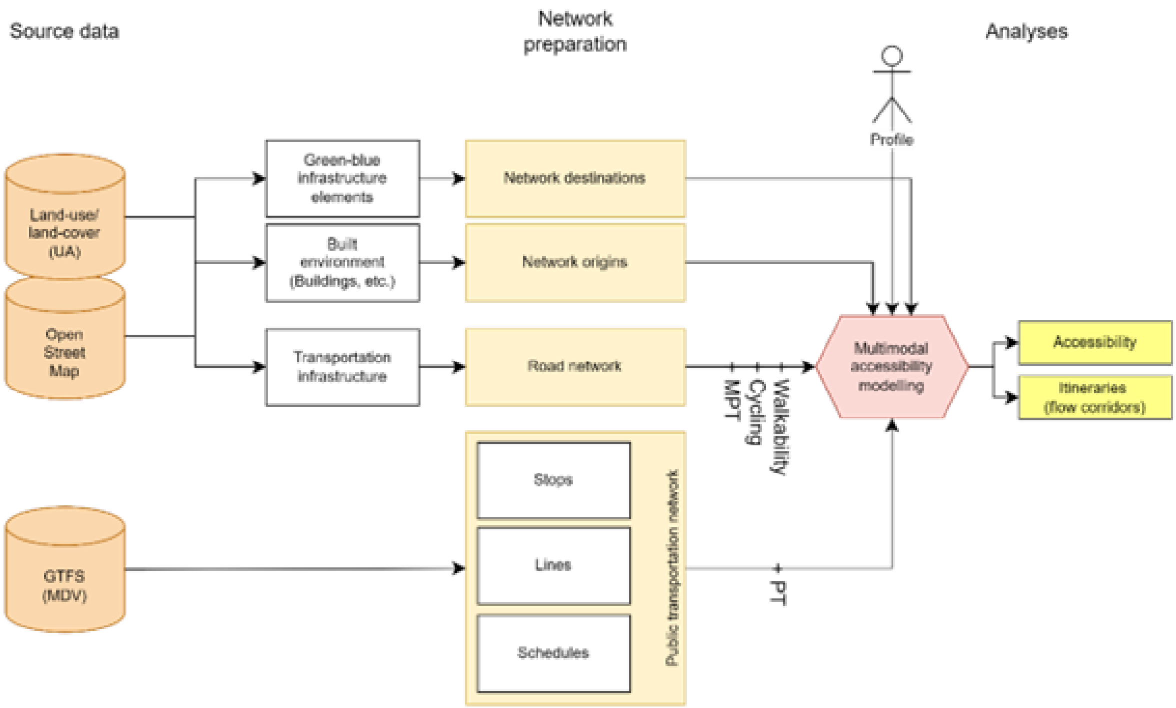

Figure 8. Multimodal socio-ecological accessibility modelling. From a set of source data including land-use/land-cover data (e.g., UA), OpenStreetMap, and GTFS data (Mitteldeutscher Verkehrsverbund/MDV), road and public transportation networks are prepared, and points of origins and destinations identified. The road network supports assessing walkability, cycling, and motorized private travel (MPT), whilst the public transportation network provides the basis for integration public transportation (PT) as mode of travel. Based on these networks, socio-ecological connectivity in terms of multimodal accessibility to green spaces at regional scale is subsequently being assessed. In the modelling process, different travel profiles may be considered, thereby imposing, e.g., varying travel time costs, or travel behaviours.

7.5.3. Task 3 - Walkability analysis

Objective

In this task, we aimed to develop an easy-to-handle and comparable tool to model walkability with a high resolution on a European scale with publicly available data and software. Adding to former research, we developed an approach for modeling the service connecting areas between residents' homes and urban green spaces (UGS). To accomplish this task, we aimed at improving the modeling of the walkable environment with a combination of population pressure and proximity aspects of green space accessibility and thus be able to detect mismatches between UGS supply and demand (Biernacka et al. 2020, Biernacka & Kronenberg 2019).

The Detour Index (DI) and Local Significance (LS) indicators that we employed not only enable small scale and high-resolution analysis of green space accessibility in single cities, but also allow for a large-scale comparison of cities and countries in Europe. The objective of this task

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was to implement the two indices we developed to demonstrate possible use cases for city planners. To describe the impact of changes in different model parameters, we tested three different scenarios and calculated the change of the index values to the base model.

Data and methods

For the analysis of the walkable environment of European cities, we required available and comparable data on public green spaces and residential buildings and their respective entry points. Additionally, the analysis required information on the population living in each residential building and a network that connects the buildings with the green spaces. We aimed to incorporate publicly accessible data and open-source software in order to allow i.) reproduction (e.g., with more recent data) and ii.) comparative approaches covering a large sample of cities. We used Urban Atlas (UA) 2018 and OpenStreetMap (OSM) as our main data sources (Fig. 9). Our first objective was to develop a modeling approach that applies the Detour Index (DI) and Local Significance (LS) walkability indices. DI is an indicator of barriers in a network. It accounts for the efficiency of the routes that residents take on their way to the nearest UGS (Wolff 2021). The LS is usually used as an indicator of edge importance in a network analysis (Esch, 2014). We use a modified version from Wolff 2021 as an indicator of how many people have access to an UGS. For computational considerations, we limited the catchment area (i.e., the distance in which the indices are calculated) around each building to 500 meters network distance. To avoid edge effects at the cities borders, we calculated the Detour Index (DI) and the Local Significance (LS) index for each UGS inside the city core plus a buffer of 1 km. We accounted for the maximum walking distance by calculating both indices for the residential buildings within a network distance of 500 m between a building entry and the nearest entry point of a UGS.

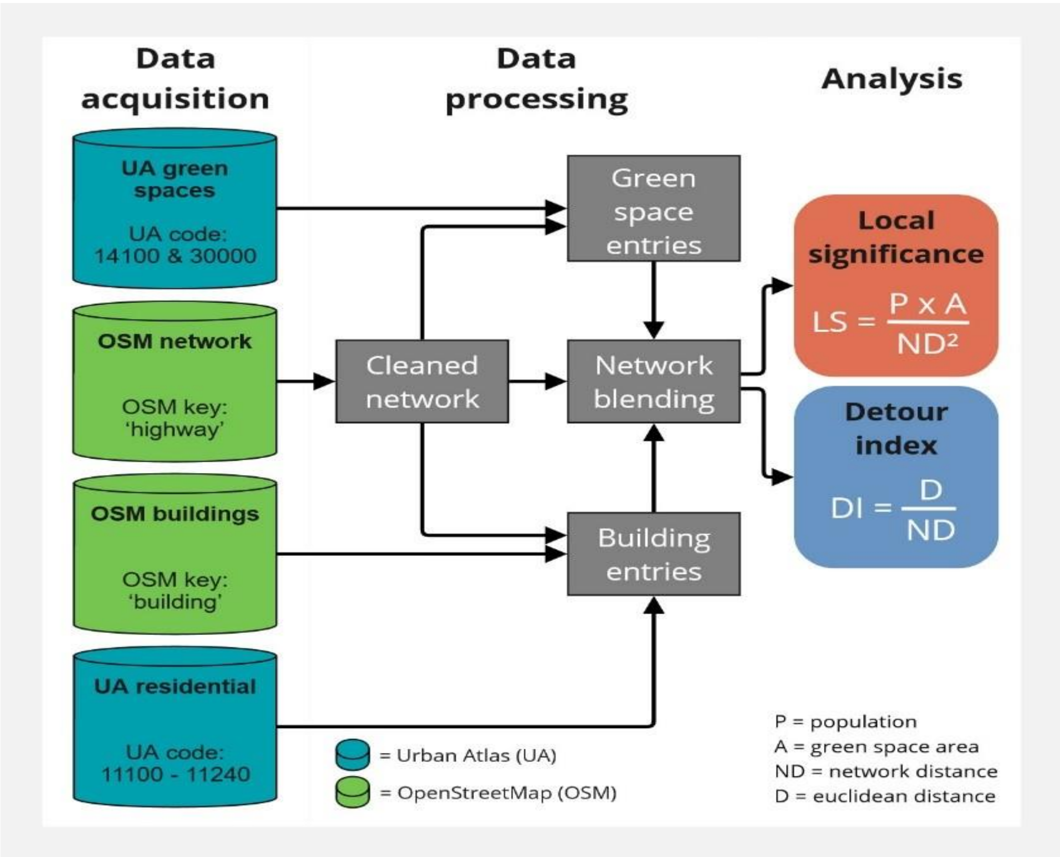

Figure 9. Workflow showing data acquisition, processing and analysis.

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Results and short conclusions

In this section we demonstrate how local planners can use the two walkability indicators that we applied before. We do so by exploring three potential alternatives in which we reshape the built environment as an expression of applied planning tools (Fig. 10). In each alternative, we alter one of the core variables that are used to calculate LS and DI.

In the first alternative, “unlimited access”, we assumed that the LVP can be accessed from all around the park. Our model could show that while overcrowding effects might be alleviated in certain areas of the park, the attractiveness of the park in general might increase, leading to a higher population pressure. For the second alternative, “densification”, we selected a number of UGS north of the LVP and replaced them with residential buildings. Here, the indicators could show that any neighbouring residents were potentially using the converted UGS for recreation. Converting them and bringing even more people in might cause the remaining UGS to be more crowded. In the last alternative, “population growth”, we assume a certain increase in residents in the area surrounding the LVP. Here, we could visualize potential crowding effects that might occur if population increasing trends tend to continue. Finally, by uniting all changes in an ensemble model, we see the complex interactions of built-up environment, population and UGS.

The implementation of the LS and DI may not only help to assess green space demands of a city. The two indices might also help city planners to test the effects of their actions regarding green and blue infrastructure on green space supply and demand before implementation. Additionally, the LS and DI may facilitate planning the street network, as well as residential units of an area together with the green and blue infrastructure, enabling synergies between departments and avoiding potential pitfalls.

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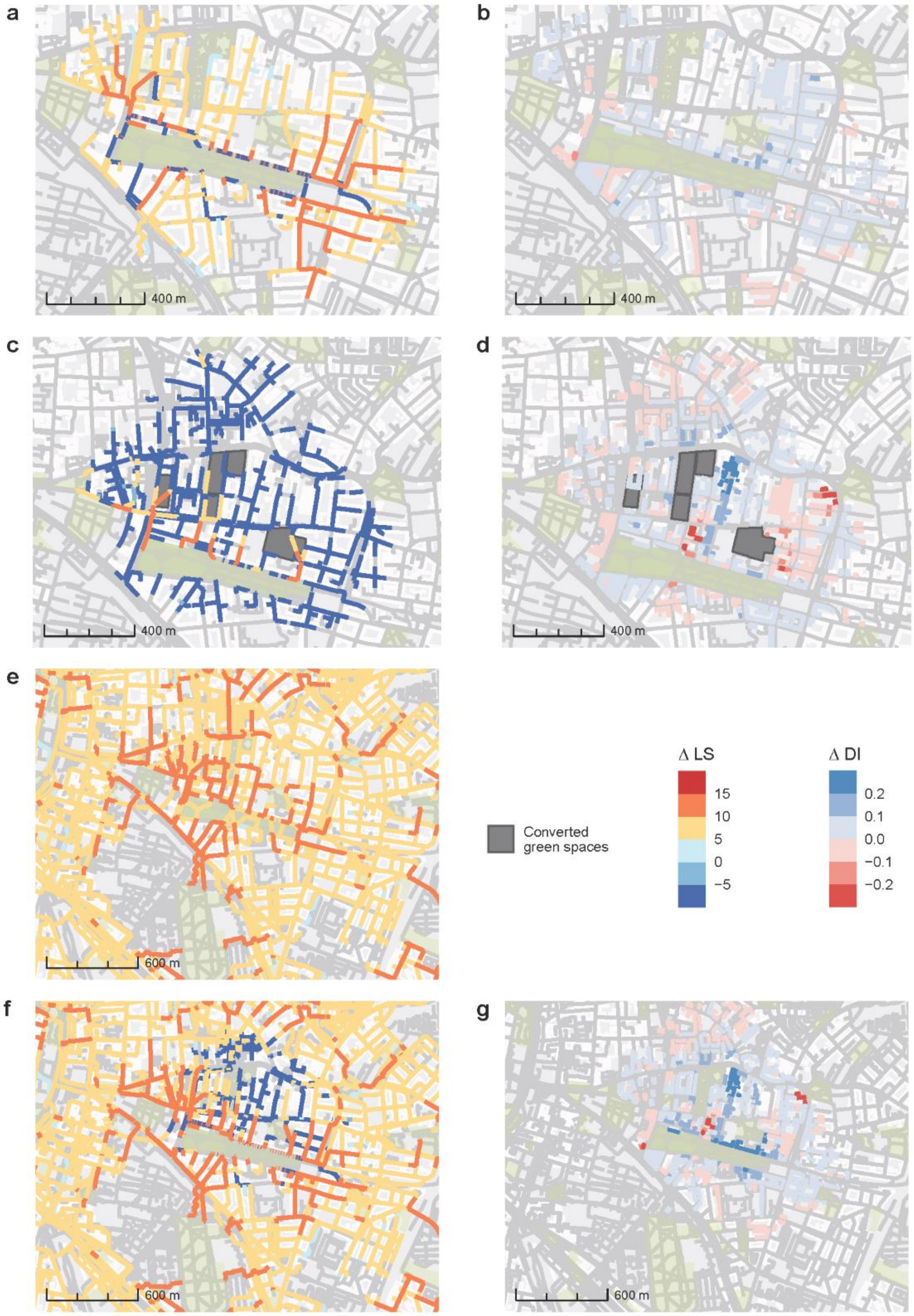

Figure 10. The figure displays how the local significance (LS) and detour index (di) values change in the different testing alternatives that we applied for the area around the Lene-Voigt-Park in the city of Leipzig, Germany.

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References

Biernacka, M. and Kronenberg, J. (2018). Classification of institutional barriers affecting the availability, accessibility and attractiveness of urban green spaces. Urban Forestry & Urban Greening, 36:22–33.

Biernacka, M., Kronenberg, J., and Laszkiewicz, E. (2020). An integrated system of monitoring the availability, accessibility and attractiveness of urban parks and green squares. Applied Geography, 116:102152.

Bodin, Ö. and Norberg, J. 2007. A network approach for analyzing spatially structured populations in fragmented landscape. Landscape Ecol. 22: 31-44.

Bodin, Ö. and Norberg, J. 2007. A network approach for analyzing spatially structured populations in fragmented landscape. Landscape Ecol. 22: 31-44.

Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) im Bundesamt für Bauwesen und Raumordnung (BBR) (2021): Green Urban Labs – Strategien und Ansätze für die kommunale Grünentwicklung. Bonn, Germany, 92p. (German)

Bundesnaturschutzgesetz (2024): *Wikipedia*, [online] https://de.wikipedia.org/wiki/Bundesnaturschutzgesetz (May 6th 2024). (German)

Chen, S., Zhang, L., Huang, Y., Wilson, B., Mosey, G., Deal, B. (2022) Spatial impacts of multimodal accessibility to green spaces on housing price in Cook County, Illinois. *Urban Forestry & Urban Greening*, 67, 127370.

City of Leipzig, Stadt Leipzig – Stadtentwicklung (2018): The specialist concepts of the INSEK Leipzig 2030, Stadt Leipzig [online] https://www.leipzig.de/bauen-und-wohnen/stadtentwicklung/stadtentwicklungskonzept-insek/die-fachkonzepte-des-stadtentwicklungskonzepts-insek-2030 (May 7th 2024).

City of Leipzig, Stadt Leipzig (2018): Integriertes Stadtentwicklungskonzept Leipzig 2030. Leipzig, Germany, 375p.

City of Leipzig, Stadt Leipzig Amt für Stadtgrün und Gewässer (2021): Masterplan Grün – Leipzig grün-blau 2030 Kurzpapier zur Zusammenfassung der Arbeitsergebnisse, 1.Fassung, Leipzig, Germany, 49p. (German)

City of Leipzig, Stadt Leipzig Amt für Stadtgrün und Gewässer (2024): Our tree-strong city campaign, Stadt Leipzig [online] https://www.leipzig.de/freizeit-kultur-und-tourismus/parks-waelder-und-friedhoefe/spenden-und-patenschaften/baumstarke-stadt (May 7th 2024).

Copernicus (2021) High Resolution Layers: https://land.copernicus.eu/pan-european/high-resolution-layers.

Dony, C., Delmelle, E. M., Delmelle, E. C. (2015) Re-conceptualizing accessibility to parks in multi-modal cities: A Variable-width Floating Catchment Area (VFCA) method. *Landscape and Urban Planning*, 143, 90-99.

Egerer, M., and Anderson, E. (2020). "Social-Ecological Connectivity to Understand Ecosystem Service Provision across Networks in Urban Landscapes" Land 9, no. 12: 530. https://doi.org/10.3390/land9120530

Funded by the European Union
NaturaConnect receives funding under the European Union's Horizon Europe research and innovation programme under grant agreement number 101060429.

Esch, T., Marconcini, M., Marmanis, D., Zeidler, J., Elsayed, S., Metz, A., M¨uller, A., and Dech, S. (2014). Dimensioning urbanization – an advanced procedure for characterizing human settlement properties and patterns using spatial network analysis. Applied Geography, 55:212–228.

European Union (2020). Mapping Guide v6.2 for a European Urban Atlas

Graphab, 2022: Documentation. https://sourcesup.renater.fr/www/graphab/en/home.html.

Gurrutxaga, M.; Lozano, P. J.; del Barrio, G. (2010): GIS-based approach for incorporating the connectivity of ecological networks into regional planning. In: Journal for Nature Conservation 18 (4), S. 318–326. DOI: 10.1016/j.jnc.2010.01.005.

Landscape Institute (2016): Connectivity and Ecological Networks. Technical Information Note 01/2016, April 2016

Lynch, A. J. (2019): Creating Effective Urban Greenways and Stepping-stones: Four Critical Gaps in Habitat Connectivity Planning Research. In: Journal of Planning Literature 34 (2), S. 131–155. DOI: 10.1177/0885412218798334.

Marzluff, J. M.; DeLap, J. H.; Oleyar, M. D.; Whittaker, K. A.; Gardner, B. (2016): Breeding Dispersal by Birds in a Dynamic Urban Ecosystem. In: PloS one 11 (12), e0167829. DOI: 10.1371/journal.pone.0167829.

Mollashahi, H.; Szymura, M.; Szymura, T. H. (2020): Connectivity assessment and prioritization of urban grasslands as a helpful tool for effective management of urban ecosystem services. In: PloS one 15 (12), e0244452. DOI: 10.1371/journal.pone.0244452.

Naturschutz in der DDR (2024): *Wikipedia* [online] https://de.wikipedia.org/wiki/Naturschutz_in_der_DDR#Landeskulturgesetz (May 6th 2024). (German)

OpenStreetMap Contributors (2020). OpenStreetMap.

Pascual-Hortal, L.; Saura, S. (2006): Comparison and development new graph-based landscape connectivity indices: towards the priorization of habitat patches and corridors for conservation. In: Landscape Ecol 21 (7), S. 959–967. DOI: 10.1007/s10980-006-0013-z.

Pereira, R.H.M., Saraiva, M., Herszenhut, D., Braga, C.K.V., Conway, M.W. (2021) r5r: Rapid Realistic Routing on Multimodal Transport Networks with R5 in R. *Findings*, 21262. https://doi.org/10.32866/001c.21262.

Reichsnaturschutzgesetz (2024): *Wikipedia* [online] https://de.wikipedia.org/wiki/Reichsnaturschutzgesetz (May 6th 2024). (German)

Rincón, V., Javier Velázquez, J. Gutiérrez, A. Hernando, A. Khoroshev, et al. (2021): Proposal of new Natura 2000 network boundaries in Spain based on the value of importance for biodiversity and connectivity analysis for its improvement, Ecological Indicators, Volume 129, https://doi.org/10.1016/j.ecolind.2021.108024.

Saura S, Pascual-Hortal L (2007) A new habitat availability index to integrate connectivity in landscape conservation planning: comparison with existing indices and application to a case study. Landsc Urban Plan 83:91–103

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NaturaConnect receives funding under the European Union's Horizon Europe research and innovation programme under grant agreement number 101060429.

NATURA CONNECT

Saura, S. Measuring connectivity in habitat mosaics: the equivalence of two existing network indices and progress beyond them. COMMUNITY ECOLOGY 2010. 11, 217–222.

Vogt, P.; Riitters, K. (2017): GuidosToolbox: universal digital image object analysis. In: European Journal of Remote Sensing 50 (1), S. 352–361. DOI: 10.1080/22797254.2017.1330650.

Wolff, M. (2021). Taking one step further – advancing the measurement of green and blue area accessibility using spatial network analysis. Ecological Indicators, 126(5):107665.

Wolff, M., Dagmar H., Jörg P., and T. Leander Hoffmann (2023): The Role of Brownfields and Their Revitalisation for the Functional Connectivity of the Urban Tree System in a Regrowing City, Land 12, no. 2: 333. https://doi.org/10.3390/land12020333.

Wolff, M., Scheuer, S., Haase, D. (2020) Looking beyond boundaries: Revisiting the rural-urban interface of Green Space Accessibility in Europe. *Ecological Indicators*, 113, 106245.

Xu, N., Guan, K., Wang, P. (in press) Improving access to urban parks through public transit optimization. *Frontiers of Architectural Research*.

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More information about the project:

NaturaConnect has 22 partner institutions: International Institute for Applied System Analysis (project lead; Austria); German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig (project co-lead; Germany); Associacao Biopolis (Portugal); BirdLife Europe (Netherlands); Birdlife International (United Kingdom); Centre National De La Recherche Scientifique (France); Doñana Research Station - Agencia Estatal Consejo Superior De Ivestigaciones Cientificas (Spain); Europarc Federation (Germany); Finnish Environment Institute (Finland); Humboldt-University of Berlin (Germany); Institute for European Environmental Policy (Belgium); Netherlands Environmental Assessment Agency (Netherlands); Rewilding Europe (Netherlands); University of Evora (Portugal); University of Helsinki (Finland); University of Natural Resources and Life Sciences, Vienna (Austria); University of Rome La Sapienza (Italy); University of Warsaw (Poland); Vrie University of Amsterdam (Netherlands); WWF Central and Eastern Europe (Austria); WWF Romania and WWF Hungary.

NaturaConnect aims to design and develop a blueprint for a truly coherent **Trans-European Nature Network** (TEN-N) of conserved areas that protect at least 30% of land in the European Union, with at least one third of it under strict protection. Our project unites universities and research institutes, government bodies and non-governmental organizations, working together with key stakeholders to create targeted knowledge and tools, and build the capacity needed to support European Union Member States in realizing an ecologically representative, resilient and well-connected network of conserved areas across Europe.

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