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Spatial priorities for a Trans-European Nature Network (TEN-N). D7.2: Variants of spatial configurations of a potential TEN-N

Louise O'Connor, Kyle J Brumm, Daniele Baisero, Andrew Plumptre, Carla Freund, Matea Osti, Jutta Beher, Thiago Cavalcante, Marta Cimatti, Marco Davoli, Jeremy Dertien, Gabrielle Deschamps, Moreno Di Marco, Néstor Fernández, Giergiczny Marek, Tom Hackbarth, Anandi Sarita Namasivayam, Michela Pacifici, Henrique Pereira, Nikolaj Rauff-Poulsen, Aafke Schipper, Sara Si-Moussi, Douglas Spencer, Marianne Tzivanopoulos, Camille Venier-Cambron, Peter Verburg, Magali Weissgerber, Heini Kujala, Piero Visconti, Martin Jung

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NATURA CONNECT

Spatial priorities for a Trans-European Nature Network (TEN-N)

D7.2 Variants of spatial configurations of a potential TEN-N

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Project reference number	**101060429**
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Author(s)	Louise O'Connor, Kyle J. Brumm, Daniele Baisero, Andrew Plumptre, Carla Freund, Matea Osti, Jutta Beher, Thiago Cavalcante, Marta Cimatti, Marco Davoli, Jeremy Dertien, Gabrielle Deschamps, Moreno Di Marco, Néstor Fernández, Marek Giergiczny, Tom Hackbarth, Anandi Sarita Namasivayam, Michela Pacifici, Henrique Pereira, Nikolay Rauff-Poulsen, Aafke Schipper, Sara Si-Moussi, Douglas Spencer, Wilfried Thuiller, Marianne Tzivanopoulos, Camille Venier-Cambron, Peter H. Verburg, Liam Vezzani, Magali Weissgerber, Heini Kujala, Piero Visconti, Martin Jung
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Deliverable description	This is the output of task 7.3 We will formulate different variants of conservation planning problems that 1) maximize the achievement of targets for species, habitats and ES (T7.1) under given constraints (including percentage area of the EU, such as 30%, including 10% strictly protected) and costs, (WP4-5); 2) ensure that the TEN-N is structurally and functionally connected (WP6) and resilient to current and future climates (T7.2); 3) incorporate present and future socio-economic constraints, costs as well as immediate conservation opportunities and challenges (using data from WP5 and WP6). Linear programming will be used to solve all problems and identify different spatial configurations of TEN-N using an adapted version of the 'prioritizr' R-package. This task will identify "win-win" solutions that achieve multiple objectives for nature and people across a range of possible TEN-

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	N characterization integrating existing values, costs, constraints and opportunities. and task 7.4 We will compute and evaluate the same indicators of performance for the existing PA network (data from T3.1, T3.2) and the proposed TEN-N variants (T7.3) to assess the coherence and adequacy for achieving its intended objectives and EU MS pledges. Performance metrics will be provided at all levels: single elements of the network (PAs and corridors), different administrative regions, biogeographic regions and the whole EU. Synergies, trade-offs and co-benefits will be estimated and summarized for each scenario (WP5), existing and proposed TEN-N node. We will identify areas of consensus and high uncertainty among alternative configurations of the TEN-N that vary in their climate change adaptation strategy, relative preference given to biodiversity (WP3) and ES (WP4) and the land-use and climate scenarios (WP5). This will indicate areas that are only selected under particular criteria, and those considered to be 'safe bets'.
Keywords	Integrated spatial prioritisation, conservation, restoration, strict protection, climate resilience, connectivity, performance indicators, feasibility, cross-border cooperation, nature's contributions to people, Nature Futures Framework, Key Biodiversity Areas

Acknowledgements

We would like to thank the many stakeholders who have engaged with this work throughout the years and provided invaluable inputs, perspectives and data validation, and have thus strengthened the resulting scientific outputs. We are sincerely grateful to all stakeholders for the time and expertise you have dedicated, both during Biogeographical Seminars and other targeted stakeholder engagement events organised as part of the NaturaConnect project. This work has also greatly benefitted from contributions from NaturaConnect partners on the conceptualisation, data and methods of the analyses. We are grateful for the UK Research and Innovation fund (UKRI) for funding the KBA scoping component of this work.

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Abbreviations

EEA	European Environment Agency
EU	European Union
EUNIS	European Nature Information System
ETC-BD	European Topic Center on Biological Diversity
GBF	Global Biodiversity Framework
GBIF	Global Biodiversity Information Facility
GI	Green Infrastructure
ILP	Integer Linear Programming
IUCN	International Union for Conservation of Nature
KBA	Key Biodiversity Area
MS	Member States
NCP	Nature's Contributions to People
NFF	Nature Futures Framework
NRR	EU Nature Restoration Regulation
ODPSCP	Overview and Design Protocol for Systematic Conservation Planning
PA	Protected area
SCP	Systematic Conservation Planning
SDM	Species distribution models
TEN-N	Trans-European Nature Network
WP	Work Package

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Executive summary

Europe has committed to ambitious biodiversity targets under the Kunming-Montreal Global Biodiversity Framework (GBF), the EU Biodiversity Strategy to 2030, and the Nature Restoration Regulation. Translating these targets to actionable area-based conservation measures, strict protection, and restoration requires a scientifically robust, transparent and reproducible approach that leads to positive outcomes for biodiversity, Nature's Contributions to People (NCP, also known as ecosystem services), ecological connectivity and resilience to climate change.

We developed an integrated pan-European spatial planning framework to identify priorities for protected area expansion, strict protection, restoration and ecological connectivity, addressing the spatial implementation of European biodiversity and restoration targets. We harnessed high-resolution pan-European ecological and socio-economic data to identify priorities under alternative planning scenarios that varied in their consideration of climate change, ecological connectivity, socio-economic costs, nature's values and the sharing of area targets among European countries and biogeographic regions. We identified consensus priority areas that were consistently selected across scenarios and evaluated their performance across a range of ecological, structural and socio-economic indicators.

The consensus priorities for conservation, strict protection and restoration provide a spatial blueprint for implementing European biodiversity policy targets as part of a coherent and resilient Trans-European Nature Network (TEN-N). In terms of performance, strategically expanding protected areas by just 5% of European land to reach 30% protection could substantially increase habitat representation from 49% in current protected areas to 69% with the expansion priorities, and species representation from 33% to 45%, while also increasing the representation of key areas for NCP, climate-resilient areas and ecological corridors. Similarly, expanding strict protection to 10% of European land could increase habitat representation from 8.0% within existing strict protected areas to 54% with strict protection priorities, and species representation from 4.7% to 27% with strict protection priorities. Only 4% of strict protection priorities enlarged around existing strictly protected areas, thus the majority of strict protection priorities extend strict protection into ecosystems that are currently underrepresented. Restoration priorities could restore 24% of potential species distributions and 31% of potential habitat distributions overall, both by restoring existing (degraded) protected areas and outside protected areas through measures such as de-intensification of land uses or restoration of natural ecosystems.

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Alternative planning assumptions resulted in substantial spatial variation in the priority areas selected and in their performance across indicators. Area-sharing rules among countries and biogeographic regions, and nature's value preferences, had a strong influence on the spatial allocation and performance of priorities, particularly for the representation of species and habitats. In contrast, explicitly accounting for climate resilience and ecological connectivity generally improved the representation of climate-resilient areas and ecological corridors without major trade-offs with other indicators.

The TEN-N can be implemented through a combination of new protected area designations, enlargement of existing protected areas (33% of protected area expansion priorities would enlarge existing protected areas), upgrading existing protected areas to strict protection (65% of strict protection priorities overlap with non-strict protected areas), and restoration of degraded ecosystems both within and beyond protected areas. At the same time, a number of priority areas for protected area expansion overlap with medium- to high-intensity productive land uses, highlighting potential implementation challenges in some areas.

Cross-border coordination emerged as an important component of a coherent TEN-N. Transboundary regions were disproportionately represented among priorities for conservation and strict protection: 62% of transboundary regions were identified as a consensus priority for at least one TEN-N objective, while strict protection expansion priorities were 47% more likely to occur in transboundary regions than expected by chance. These findings highlight the importance of coordinating conservation and restoration action across jurisdictional borders (Jung et al., 2024; Kukkala et al., 2016; Visconti et al., 2024).

These pan-European consensus priorities also have substantial potential to contribute to global biodiversity conservation. We scoped the potential of priority areas to achieve EU BDS Target 1 to meet the global Key Biodiversity Area (KBA) criteria using a scoping tool developed by the KBA Secretariat. This analysis showed that if countries updated their list of KBAs they could find that 75% of existing KBAs would be global KBAs (not regional KBAs; at present only 22% are recognised as global KBAs), 79% of the existing protected area coverage of Europe might qualify as global KBAs, and as much as 46% of the priority areas outside existing protected areas identified by the NaturaConnect conservation plan would qualify as globally significant KBAs. The European priority areas therefore have clear potential to strengthen KBA networks and contribute to implementation of the KM-GBF.

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Overall, our results provide an operational blueprint for translating European and international biodiversity targets into coordinated spatial action for conservation, strict protection, restoration and ecological connectivity. By combining robust consensus priorities with information on the consequences of alternative planning assumptions, ecological performance, socio-economic constraints and cross-border dependencies, the framework can support countries and planning authorities in developing coordinated, context-specific pathways towards a coherent TEN-N that delivers long-term benefits for nature and people.

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1. Introduction

1.1. Policy context: International area-based targets for conservation and restoration

Biodiversity is facing multiple interacting threats across Europe, including land use change, direct exploitation and climate change. These pressures not only affect species and habitats but also threaten regulating and non-material nature's contributions to people (NCP) and thus the resilience of human societies. As the climate is changing, species and habitat distributions are likely to shift. Future planning for protected and restored areas should account for climate change and help species move between protected areas to track their climatic niche.

International policy frameworks have set ambitious targets to accelerate conservation and ecosystem restoration. The Kunming-Montreal Global Biodiversity Framework (GBF) has set the target of protecting 30% of terrestrial and marine areas globally by 2030. This target has been translated at the European level within the EU Biodiversity Strategy for 2030, calling for protecting at least 30% of European land, including 10% under strict protection. In addition, the EU Nature Restoration Regulation (NRR) requires Member States to restore at least 20% of degraded land and seas. Protected areas (PAs) remain indispensable for mitigating threats, particularly habitat conversion and direct exploitation. However, current protected areas alone are insufficient to halt biodiversity decline or secure ecosystem function at continental scales (Butchart et al., 2015; Geldmann, 2026; Jones et al., 2018; Maxwell et al., 2020). To achieve meaningful and lasting outcomes for biodiversity and NCP, spatial planning should follow key guiding principles (Jung et al., 2024), so as to identify top priorities for expanding and strengthening existing PAs and for restoration, connectivity and sustainable management beyond the borders of PAs, in a way that accounts for projected scenarios of land use change and climate change.

1.2. Integrated planning for conservation and restoration: recent advances and remaining gaps

Recent years have seen considerable advances in systematic conservation planning (SCP) (Giakoumi et al., 2025). SCP studies have optimised for connectivity alongside biodiversity, climate change and NCP, yet few studies have incorporated these dimensions altogether. For

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example, spatial prioritisation has been applied to balance species and NCP at European and global scales (Jung et al., 2021; O'Connor et al., 2021), which allowed to explore synergies and trade-offs between conservation objectives. For example, focusing on NCP alone can diminish benefits achieved for species and habitats (Chapman et al., 2025; Jung et al., 2021; O'Connor et al., 2021; Strassburg et al., 2020). Other SCP studies have demonstrated the benefits of internationally coordinated planning as opposed to conservation planning at national or subnational scales. Regarding restoration planning, comparatively few prioritisation studies have optimised the allocation of ecological restoration (Chapman et al., 2025; Strassburg et al., 2020). A recent study by Chapman *et al.*, 2025 has provided valuable insights by jointly optimising conservation, restoration and production across the EU, considering species and carbon as well as sharing of responsibilities and efforts between countries. However, no study has yet directly addressed the goals of the European Biodiversity Strategy, that is where to achieve the targets of 10% strict protection, 30% protection and 20% restoration. They have furthermore been limited in taxonomic breadth, did not consider climate change or land-use change scenarios, socio-economic costs, and did not aim to balance efforts across jurisdictions while optimising across jurisdictional boundaries. Such aspects remain to be integrated and interpreted holistically alongside biodiversity, NCPs and ecological connectivity at high-resolution for Europe.

1.3. Towards a blueprint for a Trans-European Nature Network (TEN-N)

Here, we present an integrated spatial conservation plan for Europe that explicitly addresses resilience, comprehensiveness (covering multiple taxa, habitats, ecosystems and NCP), connectivity, climate and land use change, cost and equitable area sharing (Figure 1). Our analyses are designed to support biodiversity policy ambitions in Europe in line with the GBF, EU Biodiversity Strategy and NRR: Specifically, we developed a set of prioritisation scenarios that identify top priority areas for protecting 30% of European land (including 10% under strict protection), for restoring 20% ecosystems, and for sustainable management of landscapes in Europe.

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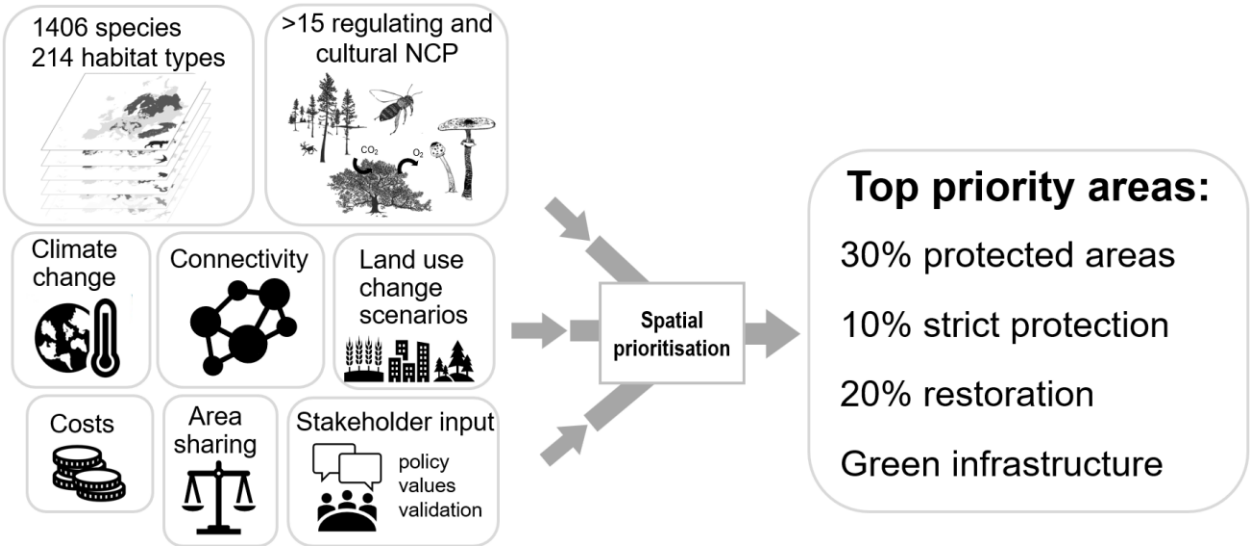

Figure 1: Conceptual workflow highlighting data integration for the design of a connected and resilient Trans-European Nature Network (TEN-N). NCP: Nature's Contributions to People. Illustrations by Camille Martinez-Almoyna.

Our aim is to offer pathways for operationalising conservation, strict protection and restoration in a way that is coherent, resilient and feasible across Europe. Using spatial prioritisation and harnessing the various existing and newly produced datasets within NaturaConnect, we create different Trans-European Nature Network (TEN-N) scenarios across a range of different design criteria, constraints and value preferences. We design the TEN-N variants to ensure: comprehensiveness and adequate representation of species, habitats and NCP; connectivity and resilience to future climate changes; feasibility through equitable sharing of conservation area between European countries and regions, and inclusion of stakeholder preferences and socio-economic opportunity costs.

1.4. Scope and objectives

The NaturaConnect project aims to create a TEN-N blueprint based on best available data and methods at pan-European scale. This encompasses the generation of a range of novel datasets, including ecological (Si-Moussi & Thuiller, 2025), ecosystem-service modelling (Schipper, 2025) and socio-economic data (Spencer et al., 2024; Venier-Cambron et al., 2025). In a previous report (Jung et al., 2024), we outlined the theoretical basis of how different criteria related to biodiversity data, costs, constraints (e.g. minimum of X% of area in a region) and area-based conservation targets can be integrated in spatial prioritizations at large scale. This deliverable describes how the data created from the NaturaConnect project was integrated, how stakeholder visions were incorporated and what variants of a truly connected TEN-N were explored through a systematic

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conservation planning approach. Part of the results described in this report have also benefited from the development of novel decision-support tools (Jung et al., 2026) specifically with regards to stakeholder validation and engagement (see Section 2.4). This report furthermore contains the approach and results taken to scope for new Key Biodiversity Areas, sites of global significance for biodiversity, across Europe.

1.4.1. Prioritisation

There is not one but multiple possible realizations of where and how the goals of the European Biodiversity Strategy for 2030 could be reached. What is relevant or practical can be directly linked to different value perspectives with regards to what requires protection, by how much or how areas should be distributed for Europe's protected areas in the future (D'Alessio, Fornarini, et al., 2025). Thus, we created multiple "variants" of plausible configurations of a TEN-N providing stakeholders such as European policy makers with a range of options of where area protection, strict area protection and restoration could be implemented. Each variant integrates new data made available from the NaturaConnect project at a 1 km² spatial resolution across Europe. We also describe how different variants can be combined into one "consensus" layer that helps to identify 'safe-bet' areas that are consistently selected across multiple scenarios. The obtained consensus layer for conservation, strict protection and restoration was then evaluated through a stakeholder feedback process, in which key stakeholders such as planning authorities were invited to provide spatial-explicit feedback, which helped to evaluate potential gaps and errors early on. Lastly, each variant was evaluated using a range of different performance indicators developed within the project, which measure for example the number of species, habitat and NCP covered by the variant, or whether a specific variant is more likely to be climate resilient, ecologically connected or otherwise coherent.

1.4.2. KBA scoping

Key Biodiversity Areas (KBAs) are globally significant sites for conservation (Butchart et al., 2026; Plumptre et al., 2023). They are recognized in the EU Taxonomy and the Corporate Sustainability Reporting Directive (CSRD) as areas of biodiversity significance, sites where negative impacts are to be avoided by the activities of companies. They are also used in indicators of the UN Sustainable Development Goals 14 & 15, the Kunming-Montreal Global Biodiversity Framework (GBF), Convention on Migratory Species and the Ramsar Convention on Wetlands. They are increasingly being used by the private sector to identify important areas for biodiversity in

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reporting frameworks (e.g. CSRD, TNFD, SBTN, GRI), as well as by funding agencies to guide investment in biodiversity conservation. NaturaConnect aims to identify priority sites for European conservation based on European targets and objectives, but many of these sites will also hold globally significant biodiversity values. The KBA Secretariat, hosted by BirdLife International in Cambridge, UK, has developed a Scoping Tool that is able to evaluate global biodiversity significance, and is able to highlight the KBA potential for sites. By performing a scoping of the NaturaConnect solutions, we can identify which regions are most likely to contribute to global conservation objectives and be recognized as global KBAs, directly contributing to international reporting mechanisms.

2. Methodology

2.1. Objectives and workflow

Prioritisations for conservation, strict protection, and restoration are run in sequence. Our approach involves establishing sequential contributions of different types of conservation actions towards the protection and recovery of biodiversity, such that: conservation, strict protection and restoration should have the biggest contribution to biodiversity targets. In addition, we considered that conservation and restoration are not mutually exclusive: policy guidance for the Nature Restoration Regulation notes that restoration can be carried out both within and outside protected areas, with a focus on restoring degraded ecosystems within protected areas by 2030. The sequence in each variant scenario (Figure 2) is as follows:

(1) **Identify top priorities for 30% conservation**, expanding on existing protected areas.
(2) **Identify top priorities for 10% strict protection**, within the 30%. These priorities expand on existing strictly protected areas. The area available for strict protection per grid cell is capped by the amount selected for 30% conservation (including existing non-strictly protected areas as well as expansion priorities), as the 10% are nested within the 30% by definition.
(3) **Identify top priorities for 20% restoration**. Feasible restoration transitions are informed by the current and future land system maps, as well as existing protected areas. In line with policy guidance and implementation realities, we designed the problem to allow restoration priorities to be selected both within and outside existing protected areas.

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(4) **Prioritise green infrastructure (GI),** by ranking the rest of Europe, i.e., areas beyond the priorities for 30% protection, in terms of multifunctional value for connectivity, NCP and any remaining gaps in species and habitats coverage.

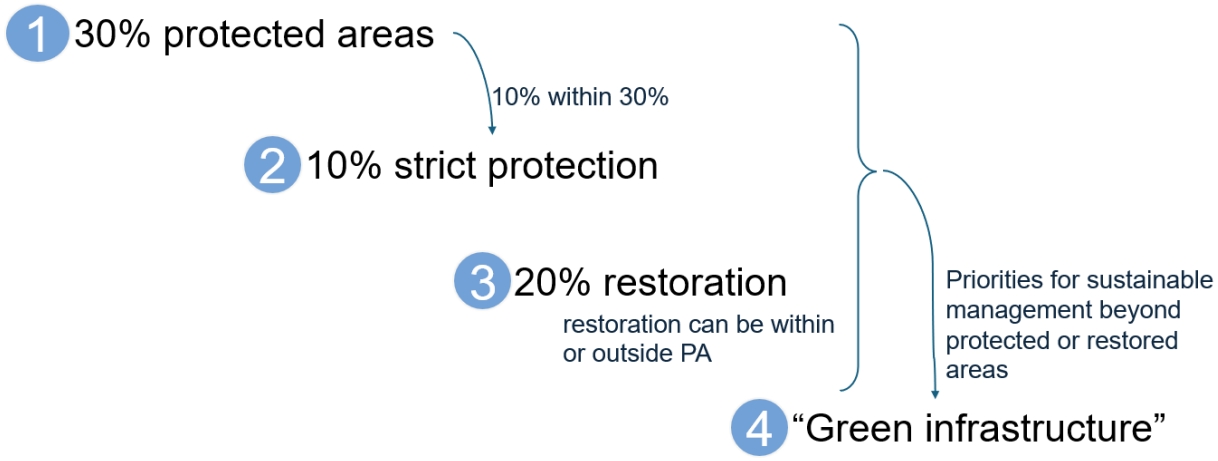

Figure 2: Overview of the prioritisation sequence.

2.2. Input data

The integrated spatial planning scenarios consider a range of inputs from the NaturaConnect project: spatial distribution data for species (vertebrates, invertebrates and plants), habitats and NCP in present-day and future scenarios; ecological resilience to future climate scenarios based on climate-driven range shifts; ecological connectivity, both functional and structural; alternative land use change scenarios; NCPs, and opportunity costs.

2.2.1. Study area and planning units

The study region encompasses all European Union Member States, as well as Norway, Iceland, the United Kingdom, Switzerland and non-EU Balkan countries. We identify top priorities for 30% protected area expansion, 10% strict protection and 20% restoration targets in the pan-European region (including EU and non-EU countries) to support coordinated European-scale planning. These targets correspond to commitments under the EU Biodiversity Strategy for 2030 and Nature Restoration Regulation within EU Member States. For non-EU countries, protected area expansion priorities and restoration priorities can support the realisation of KM-GBF Targets 2 and 3. The study region comprised over 5 million planning units, which consist in raster grid cells

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of 1 x 1 km², matching the available spatial input data for species, habitats, NCP, connectivity, opportunity costs, and land systems.

2.2.2. Biodiversity features

Species and Habitats. The spatial planning includes high-resolution spatial data on the European distributions of species and habitats of conservation concern for which there is sufficient occurrence data to model their distributions (Si-Moussi et al., 2025; Si-moussi & Thuiller, 2024; Si-Moussi & Thuiller, 2025). We consider species and habitats that are listed in the Annexes of the Article 12 Birds Directive and Article 17 Habitats Directive, as well as those that are assessed as threatened or near-threatened in the European and Global IUCN Red Lists of species and ecosystems, and any other species that are endemic to Europe (Table 1). This is in line with existing policy guidance suggesting that "...additional designations will also focus on the protection of habitats and species that are not covered by the EU nature legislation and especially those identified in European or national red lists" (European Commission, 2022). Species included consist of terrestrial vertebrates (773 species), vascular plants (187 species), and arthropods (446 species). Habitat types included span grasslands (55 habitats), forests (40), scrub and tundra (36), coastal and littoral (32), freshwater (10), wetland (20), and sparsely vegetated habitats (26). In the context of the NaturaConnect project we primarily focus on terrestrial biodiversity, but freshwater biodiversity (rivers, lakes, wetlands) is also considered to some extent through the inclusion of semi-aquatic species (e.g. amphibians, water birds, otters, beavers, desmans, odonates) and of wetland/freshwater habitat types. We used current and future distributions of species and habitat distributions from WP3 as features after some post-processing (see below). EUNIS level 3 habitat distributions were modelled (Si-Moussi & Thuiller, 2025); however, not all of these habitats are in need of conservation, therefore we only considered those habitats which corresponded to habitats of policy interest listed under Article 17, using crosswalks of EUNIS to Article 17 habitats classifications. In total, we included in the prioritisation 233 habitat types and 1,406 species of vertebrates, plants, and invertebrates.

We refined the spatial distributions data for the prioritisation, notably following feedback received by stakeholders and local experts across Europe in the validation of our preliminary model outputs. Specifically, we masked out from Habitat Distribution Models any areas that are under high density of urbanisation and infrastructure (based on CORINE 2018 version). To do so, we created a layer that merged industrial units, urban fabric, airports, mineral extraction sites, dump sites, roads and rail, construction sites, and refined the habitat distribution maps by

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reducing habitat suitability proportionally to the amount of urbanisation and infrastructure per grid cell. For the prioritisation for conservation and strict protection, we filtered out unsuitable habitats from the SDM based on known habitat preferences of vertebrate species (O'Connor et al., 2024), as the aim is to identify remaining habitats of high suitability. For conservation, we retained the continuous suitability above the TSS threshold to retain the information about quality of habitat for species. For more information about the TSS for species distribution models, see D3.2 (Si-Moussi et al., 2025). For restoration, we binarized the unfiltered SDM (grid cell with a probability value above TSS were assigned a value of 1, else 0) as a proxy for the maximum potentiality of species distributions in the absence of land use constraints (Si-moussi & Thuiller, 2024). Future projections of SDM do not account for dispersal capacity, therefore we assumed limited dispersal and excluded all areas of future suitability that are not within the current distribution of the species and habitats, to restrict the prioritisation to areas that are suitable and within reach for the species.

Nature's Contributions to People. In the Nature as Culture and Nature for Society prioritisation scenarios, we use current and future NCP distributions as biodiversity features alongside species and habitat distributions. We used NCP supply and flow layers were modelled and mapped by NaturaConnect (Schipper, 2025). Each NCP is standardized between 0 and 1 and included in the prioritisations as an individual feature. For the conservation prioritisation, the flow layer for each NCP in the current land system is used as biodiversity features alongside species and habitats; for the restoration prioritisation, the flow for each NCP under future NFF land use change scenarios are used as features. The inclusion and weighting of each of these NCP varied in different prioritisation variants and objectives, according to alternative Nature Futures Framework narratives (D5.1) (see sections 2.2. and 3.5.). Specifically, NCP covered in the analyses are:

- 10 Regulating NCP: Pollination (Vezzani, 2025); Soil erosion protection (Spencer, 2025); Carbon Sequestration and Carbon Stocks (Sarita Namasivayam et al., 2025); Agricultural pest control (Civantos et al., 2012); Carrion elimination; Mosquito biocontrol; Regulation of processionary pine moth; Regulation of bark beetle; Regulation of tick-borne pathogens; Seed dispersal (O'Connor et al., 2026).
- 9 Cultural NCP: Wildlife watching (O'Connor et al., 2026); Wild foods foraging (vascular plants) (Schulp et al., 2014); Nature recreation (Giergiczny et al., 2025; Scheuer, 2025); Heritage forests and Heritage agriculture (Tieskens et al., 2017); Birdsong; Medicinal plants.

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Table 1: Number and policy relevance of species included in the prioritisation. Abbreviations: VU = vulnerable; EN = endangered; CR = critically endangered.

	Total included	EU policy framework	Threatened in Europe (VU/EN/CR)	Endemic to Europe
Vertebrates	773	445 birds included in Birds Directive Article 12 reporting 243 mammals, reptiles, amphibians included in Habitats Directive Article 17 reporting	123 threatened; 66 near-threatened	269
Plants	187	180 included in Article 17 reporting	42 threatened; 33 near-threatened	116
Arthropods	446	45 included in Article 17 reporting 311 pollinator species	67 threatened; 67 near-threatened	239
Habitats	233	233 included in Article 17 reporting	44 threatened ; 15 near-threatened	NA

Other ecosystems of conservation importance. EU Commission Guidance on protected areas specifically notes that remaining primary and old-growth forests and any significant areas of carbon-rich ecosystems, such as peatlands, should be strictly protected. Primary and old growth forests are included as features, with a very high weight of 10,000 to ensure their selection in the output for conservation and strict protection. The spatial data on remaining primary and old-growth forests combine multiple datasets on European old growth and primary forests, including that developed by (Sabatini et al., 2018) and old-growth forests in the Carpathians (unpublished inventory of (quasi-) primary forest shared by EEA). We also covered species and habitats of major importance for reaching the ambition of the European pollinator strategy, based on pollinators' natural habitat mapped in WP4 (Schipper, 2025).

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Structural connectivity among habitats. We additionally included structural connectivity layers, modelled as the effective mesh size for each EUNIS Level 3 habitat type (Poulsen et al., 2025), as biodiversity features input, in the prioritisation variants that considered ecological connectivity to ensure that well-connected and unfragmented habitats are prioritised.

2.2.3. Constraints and penalties

2.2.3.1. Protected areas

The prioritisation for conservation and strict protection complement, and expand on, existing protected areas. We extracted spatial data on Natura 2000 sites for EU Member States from the EEA database (accessed from https://www.eea.europa.eu/en/datahub/datahubitem-view/6fc8ad2d-195d-40f4-bdec-576e7d1268e4?activeAccordion=1099600%2C1095306), and on all other protected areas from the World Database on Protected Areas (accessed from protectedplanet.net) together with their IUCN protected area management categories to distinguish strictly protected areas (categories I and II) from other categories. We rasterised the polygon data such that the value of each 1 x 1 km grid cell of these protected area layers contained the proportion of area that is protected. Currently, protected areas including all designations and management categories cover 25% of European land area; Natura2000 sites cover 19% of EU land area; and strictly protected areas cover 4% of European land area. We use Natura 2000 sites and nationally-designated sites (NatDa) as the starting point for protected area expansion in the solution for the 30%, with two variants (that differ only for the protected areas considered as baseline in EU countries): one that only considers Natura 2000 sites, and one that expands on all protected areas. As of conducting this work, no specific information is available on which Nationally designated sites will count towards the 30%; but all Natura 2000 sites must count. We note that this estimate of baseline protection includes all indicated existing sites, while often many sites may not have the protection of biodiversity as primary objective depending on the interpretation (Pedersen et al., 2026). The fraction of existing protected area per planning unit is included as the lower bounds in the manual bounded constraints in the prioritisations for protected area expansion, so that, at minimum, the proportional amount that is currently protected per planning unit gets selected in the solution (see below, equation 6). For the 10%, we defined top priorities for strict protection to expand on reserves and national parks: we use IUCN protected area categories I and II which are typically used as baseline for strict protection (Cazzolla Gatti et al., 2023), in the absence of better data on existing strictly protected areas at the European level. We extract spatial data on protected areas classified under IUCN categories I and II from the

WDPA (protectedplanet.net), and lock them into the solution for strict protection (i.e., we use the fraction of each planning unit currently covered by these strictly protected areas as the lower bounds of the manual bounded constraints in each planning unit for strict protection within prioritizr). Note that data on OECM (Other Effective area-based Conservation Measures) were not available and their definition was still debated at the time the analyses were performed, thus we do not consider OECM here, but we note that OECM can be a tool to sustainably manage ecosystems outside of conventional protected areas (e.g. for ecological corridors and green infrastructure).

2.2.3.2. Climate resilience

We include areas of high importance for the persistence of terrestrial vertebrates under climate change, hereafter climate-resilient areas (Cavalcante et al., 2025a, 2026). These areas represent priorities for conserving both present and future suitable habitats and maintaining connectivity between them, while accounting for species-specific dispersal abilities and the different climatic conditions occupied by species across their ranges. Climate-resilient areas are integrated in the prioritisation as a linear penalty with a negative penalty value to preferentially select climatically resilient priority areas. More information on the climate resilient priorities identified in T7.2 is available in Deliverable D7.1 (Jung et al., 2024). To adjust our planning criteria based on stakeholder preferences for climate change resilience, we elicited specific stakeholder preferences on three separate occasions on a sample of >100 regional delegates and experts from 13 EU Member States (Finland, Sweden, Estonia, Latvia, Lithuania, Cyprus, Spain, France, Greece, Italy, Malta, Portugal, Croatia) using Menti. When asked the question “How much would you be willing to give away resources from the protection of species current habitats to protect their future habitat? (0-100%)”, delegates responded with an average of 37%. We used this stakeholder input to adjust the penalty value, such that priorities that include climate resilience are 37% different spatially than priorities that ignored climate change, which corresponded to a negative penalty value of -0.002.

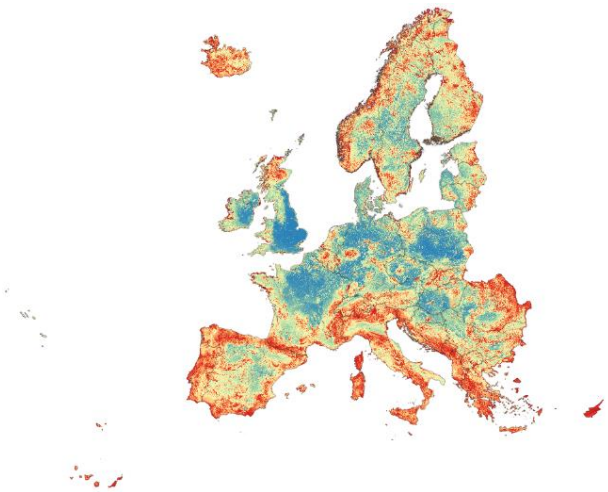

Figure 3: Climate-resilient areas for vertebrates in Europe (from T7.2) used as input layer in the prioritisation. Values range from 0 for low importance (blue) to 1 for high importance (red) which represent climate-resilient areas for terrestrial vertebrates that account for climate niche tracking via dispersal.

2.2.3.3. Ecological corridors

In the variants that consider ecological connectivity, both structural and functional connectivity is considered. For structural connectivity, a probability-weighted fragmentation metric estimated for all EUNIS Level 3 terrestrial habitats is included as biodiversity features to prioritise well connected and unfragmented habitats (Poulsen et al. 2025). For functional connectivity, we included critical ecological corridors that enable species movement between protected areas. This layer was produced by combining circuit theory (omniscape) and graph theoretical approaches (dpC) to identify priority corridors (proxied by randomised shortest paths) across all functional species archetypes of non-flying vertebrates (Dertien et al., 2025). We incorporate this layer as a linear penalty with a negative penalty score of -0.002 to balance with the optimisation of other biodiversity features. This ensures that the areas selected for conservation or restoration will be selected not only for their value for species, habitats and NCPs, but also protected for their role as stepping stones for many European species. We evaluated the trade-offs across different variants that include or ignore connectivity, in terms of the amount of species and habitat distributions, and the amount of critical corridors represented in the 30%.

2.2.3.4. Socio-economic opportunity costs

Initial discussions with stakeholders (see also Jung et al., 2026) confirmed that important barriers for conservation and strict protection are socio-economic costs; thus we provided a set of scenarios that include socio-economic costs in addition to biodiversity features. In SCP, cost

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estimates can be quite impactful and drive protection priorities (Kujala et al., 2018). To analyse the trade-offs in including or excluding a cost layer, in the planning we provided two sets of scenarios, one with equal costs for all planning units, and a second set of scenarios that include socio-economic opportunity costs data (Spencer et al., 2025). Costs were mapped at a 1 km² resolution by WP4, separately for each land system: urban, forest, croplands. When using costing data, we incorporate these costing data in the problem as linear penalties with a penalty score that ensures that the cost does not compromise achieving the area budget, and is emphasised differently under each NFF scenario. To explore the implication of different local communities' willingness to pay for conservation under different value perspectives, when costs are applied, the penalty score varies for each NFF pathway. For the Nature for Nature perspective, we apply a low penalty of 0.001, thus placing more emphasis on achieving biodiversity objectives with limited influence of the opportunity costs. In the Nature for Society scenarios, a higher penalty of 0.1 for costs are applied so that more stringent forms of management tend to avoid areas with high opportunity costs, to avoid conflicts between conservation and human activities. In the Nature as Culture perspective, which emphasises land sharing and co-existence of people and nature, we apply an intermediate penalty score of 0.01 to balance priorities for protected area expansion for biodiversity and people and enable the protection of culturally significant landscapes such as high-nature value agricultural areas.

2.2.3.5. Land available for conservation and restoration

We used the fraction of terrestrial area per planning unit as a first constraint to cap the possible selected area to terrestrial land. Further, we used a novel map of European land systems to constrain the selection of priority areas for specific land systems and land use intensity levels (Sandström et al., 2024). For conservation, strict protection and restoration, we prevented the selection of additional area in settlements (rural, peri-urban and urban), based on the European land systems map (Sandström et al., 2024). For conservation and strict protection, we further prevent additional protection in planning units that are dominated by high-intensity arable cropland or high-intensity needle-leaf forests, as these are assumed to be depleted of ecological value in current land systems and would first need to be restored to recover meaningful ecological value. Restoration priorities are defined as the top 20% of land that is degraded yet restorable that would most benefit biodiversity and NCP in current and future climate and land use. To avoid the selection of areas with a high density of anthropogenic infrastructure that is unlikely to be protected or restored, we additionally created a spatial layer that merged the following CORINE classes: urban fabric, industrial units, airports, mineral extraction sites, dump sites, roads and rail,

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construction sites. We used this as a constraint in the prioritisation to prevent the selection of these areas for conservation proportionally to the amount of anthropogenic infrastructure per planning unit.

To prioritize areas for ecological restoration, we focus on areas that are currently degraded but restorable. As a proxy for ecological degradation, we use all human-dominated land systems (medium to high intensity forests; medium to high intensity grasslands; all croplands; forest/crops mosaics and forest/grassland mosaics), and exclude land systems that are already natural or semi-natural in the current land systems map (wetlands, water bodies, low-intensity (LI) forests, LI grasslands, and bare/rock/shrub areas). Restoration priorities encompass land use transitions that either restore natural habitats (which are: LI forests, LI grasslands, bare/rock/shrub, wetlands), or de-intensify within the same land cover type. For restoration, feasibility is defined by both 1) existing protected areas that are dominated by extractive land uses of medium to high intensity and 2) transitions in land use change scenarios (D5.2). We use the current land system map (Sandström et al., 2024), and three alternative nature-positive future land-use change scenarios (Venier-Cambron et al., 2025), informed by three contrasting Nature Futures Framework (NFF) narratives specifically co-developed with stakeholders for Europe: Nature for Nature, Nature for Society and Nature as Culture (D'Alessio, Fornarini, et al., 2025). This ensured that the TEN-N integrates societal perspectives on future biodiversity protection in Europe, accounting for multiple values and perspectives of nature. By using the NFF framework, NaturaConnect aligns with global efforts on scenario development auspicated by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). The development of the narratives considered the global and European policy context as a starting point and included a stakeholder engagement process conducted to elicit stakeholders; preferences and visions in relation to future nature conservation and management in Europe. These narratives present contrasting perspectives and priorities for seven themes: Protected areas, Connectivity and Restoration, Forestry, Freshwater ecosystems, Urban system, Agriculture, Energy. These topics are key to building a more positive future for nature and people. Besides specificities for each narrative, we also identify commonalities across the three perspectives, including macroeconomic trend assumptions, biodiversity strategic goals of the European Union and shared solutions that are necessary to achieve any positive nature future (D'Alessio, Fornarini, et al., 2025).

The contribution of the NFF in the context of TEN-N design is twofold: (a) its ability to hold a plurality of perspectives on what is desirable, which enables the development of joint goals and visions and recognizes the possible convergence and synergies of measures to achieve these

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visions and (b), its multiscale functionality for elaborating scenarios and models that can inform decision-making at relevant levels, making it applicable across specific places and perspectives on nature. Here the NFF can be used as a navigation tool helping to make diverse, desirable futures possible. In the restoration prioritisation, we used the modelled NFF land use scenarios to set the lower and upper bounds on feasible restoration in each 1 km² planning unit outside of existing protected areas. Thus, land use change scenarios are not regarded as an inevitable future outcome but can instead be informed by complementary priorities for biodiversity conservation and restoration. Land use change projections are used as input only for restoration priorities, but not to constrain priorities for protected area expansion: this is because, if the planning unit would be a top priority for protected area expansion with the current land-use class (given its suitability for current and future distributions of biodiversity and NCP), then the current land use should be conserved, regardless of predictions in the (biodiversity-blind) land-use change scenarios.

2.2.3.6. Ecological integrity

For strict protection, the prioritisation variants that emphasized the intrinsic value of nature (i.e., Nature for Nature; see section 2.3.5.1) included a spatial proxy for ecological integrity. The ecological integrity layer combined three dimensions of ecosystem integrity: low fragmentation, low human pressure, and high trophic complexity. Low fragmentation was derived from landscape connectivity, measured using effective mesh size which captured the degree of habitat fragmentation and the continuity of areas not separated by major anthropogenic barriers (Weissgerber et al., in preparation). Low human pressure was proxied by low HANPP, which measures the human appropriation of biomass through grazing and forestry (Matej et al., 2025). Trophic complexity was represented by the diversity of trophic interactions among terrestrial vertebrates, measured as the number of trophic interactions occurring within each planning unit (O'Connor et al., 2025). The connectivity and land-use components were first combined into an ecological integrity layer, with higher values representing low fragmentation and low human pressure (Weissgerber et al., in preparation). We then incorporated local trophic complexity by normalising trophic interaction diversity to a 0-1 scale and multiplying it by the ecological integrity layer. The resulting indicator therefore assigns higher values to areas of low fragmentation, low human land-use intensity, and high trophic complexity. The final layer was rescaled to a 0-1 range and used in the prioritisation as a negative penalty, to encourage the selection of areas of high ecological integrity under the Nature for Nature variants.

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2.3. Mathematical formulation of the prioritisation

2.3.1. Problem formulation

We solve the problem as a linear programming problem, using the R-package *prioritizr* version 8.0.4 (Hanson et al., 2025) and the Gurobi solver for fast identification of the optimal solution (Gurobi Optimization, 2024). Planning units are 1 x 1 km² grid cells. We use a minimum shortfall objective function, minimizing the shortfall to targets among features. Features included vary between scenarios as detailed in the previous section, according to: 1) the NFF perspective (see section 2.3.5), 2) the objective (e.g. restoration, conservation, strict protection), and 3) whether connectivity should be considered for the 30%. Mathematically, the problem formulation is expressed as follows (see parameters in

Table 2):

$$\boldsymbol{Minimize}\left[\sum_{f}^{F} \boldsymbol{w_f}\, \boldsymbol{y_f}\right] \tag{1}$$

$$\boldsymbol{subject\ to}: \tag{2}$$

$$\sum_{p}^{P} \boldsymbol{x_p}\, \boldsymbol{r_{fp}} + \boldsymbol{t_f y_f} \geq \boldsymbol{t_f} \quad \forall \boldsymbol{f} \in \boldsymbol{F} \tag{3}$$

$$\sum_{p}^{P} \boldsymbol{x_p c_p} \leq \boldsymbol{B}$$

where $\boldsymbol{x_p} \in [\boldsymbol{0}, \boldsymbol{1}]$ is the decision variable, i.e. the proportion of area in planning unit $\boldsymbol{p}$ selected in the solution; $\boldsymbol{r_{fp}}$ is the amount of feature $\boldsymbol{f}$ in planning unit $\boldsymbol{p}$, $\boldsymbol{t_f}$ is the representation target for feature $\boldsymbol{f}$, $\boldsymbol{y_f} \in [\boldsymbol{0}, \boldsymbol{1}]$ denotes the relative representation shortfall for the target $\boldsymbol{t_f}$ for feature $\boldsymbol{f}$, and $\boldsymbol{w_f}$ is the weight for feature $\boldsymbol{f}$. Additionally, $\boldsymbol{B}$ is the budget allocated for the solution: 30% land area for conservation; 10% area for strict protection and 20% for restoration.

The representation target $\boldsymbol{t_f}$ for each feature f is specified conditionally as follows (see section 312.3.2.2). For non-threatened features, the target is to protect all remaining distribution; and for non-threatened species and habitats, the target was set to 80% and 70% of current distribution, respectively. Therefore:

(4)

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$$t_f = \begin{cases} r_f, \text{if } f \text{ is threatened} \\ 0.8\ r_f, \text{if } f \text{ is a nonthreatened species} \\ 0.7\ r_f, \text{if } f \text{ is a nonthreatened habitat} \\ 0.5\ r_f, \text{if } f \text{ is a NCP} \end{cases}$$

We impose limits on the amount of area that can be selected per grid cell: in the prioritisations for conservation (and strict protection), existing (strict) protected areas were included d_p as lower bound constraints, ensuring that currently protected fractions of each planning unit remained selected in the solution so that priorities expand on existing protected areas. The upper bound is determined by the fraction A_p in the planning unit available for conservation, strict protection or restoration. In practice, these limits are implemented using manual bounded constraints in *prioritizr*. (5)

$$d_p \leq x_p \leq A_p$$

In the prioritisation variants with equal % area sharing among countries or biogeographic regions we imposed regional unit budget constraints. We apply linear constraints D_i such that for each country or biogeographic region $i \in I$ the amount of area selected as a priority per unit is between a lower bound L_i and upper bound U_i to the set of planning units p within a given geographic area i:

$$L_i \leq \sum_{p}^{P} (D_{ip}\ x_p) \leq U_i, \forall\ i \in I \quad (6)$$

Table 2: Key parameters in the mathematical formulation

Parameter Name	Symbol	Purpose
Planning unit	$p \in P$	Identifies the specific planning unit where the action is applied. In our case, planning units are 1km² grid cells.
Feature	$f \in F$	A specific feature included the planning process, e.g., a species, habitat, or NCP.
Amount	r_f	The amount of area of a given feature *f* (*i.e.* its range)
Target	t_f	A specific area target set to each feature *f* that is expressed in the same unit as r_f

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Weight	w_f	A weighting set specifically for a given feature w_f and that it determines its weight relative to other features *f*
Decision	$x_p \in [0,1]$	A constant stating the total share of the planning unit *p* that is being selected in the solution.
Solution	x_P	The total of the decision space for all given planning units *P*
Cost	$c_p = 1$	Cost of selecting a given planning unit. Here the cost is simply proportional to the amount of (terrestrial) area in a grid cell – this is to be able to express the budget in terms of area, to reach the 30%, 20% and 10% area targets in the EU Biodiversity Strategy. Note that this cost here is different from the socio-economic cost layer, which is included separately, as a linear penalty.
Area sharing constraints	$\boldsymbol{D_{ip}}$	Linear constraints applied to the decision problem given as lower $\boldsymbol{L_i}$ and upper bounds $\boldsymbol{U_i}$ to the set of planning units *p* within a given geographic area *i*. For 30% conservation, the upper bound is 30% (or current amount protected in the country or region, if above 30%) and lower bound is 25%. For strict protection, the upper bound is 15% of the country or region area; and the lower bound is 0%. For restoration, the upper bound is 30% minus the amount selected for strict protection; and the lower bound is 0%.
Administrative unit	$i \in I$	Biogeographic region or country
Manual bounded constraints	d_p A_p	$\boldsymbol{d_p}$ is the proportion of planning unit *p* that is currently protected, that must be included in the solution at minimum (set as the lower bound). $\boldsymbol{A_p}$ is the proportion of planning units that is available for conservation, strict protection or restoration.

2.3.2. Setting feature weights and targets

2.3.2.1. Feature-specific weights

A key element of SCP is the option to assign more importance to some features than others through the setting of weights (Arponen et al., 2005).

A first component of weights was the conservation status (using both the IUCN Red List status and Article 17 reported status) of species and habitats. We built on previous studies to assign weights to ensure that threatened species and ecosystems are prioritised over non-threatened features (Jung et al., 2021; Pouzols et al., 2014). We define a weight w_f for each threatened species or habitat based on their Red List status (using both the Red List of Species and the Red

List of Ecosystems). Species or habitats known to be Critically endangered (CR) or in bad conservation status (U2) were given a weight of 5, Endangered (EN) a weight of 4; and Vulnerable (VU) or unfavourable conservation status (U1) a weight of 3. Near threatened (NT) and Data Deficient (DD) species or habitats were given a weight of 2. All other species and habitats were given a weight of 1. For species, we used all available Red List assessments at the Global and European levels. We obtained the Red List weighting by averaging the value across European and Global Red List.

We collected stakeholder preferences both by means of a survey addressed to NADEG representatives in summer 2023, and in person to Member State delegates during the biogeographic seminars (Boreal and Mediterranean). The responses revealed a high variation in individual preferences such that overall, no single group of biodiversity feature emerged to be considered significantly more important than others, but vary depending on value perspectives.

We thus ran variant scenarios that vary the weighting of species, habitats, regulating NCP and cultural NCP to reflect value preferences in the Nature Futures Framework (see section 2.3.3 for more details).

2.3.2.2. Feature-specific targets

Targets represent the minimum amount of the spatial distribution of each species or habitat that should at minimum be protected, with the objective to minimise target shortfall for species not only across the 30% protected areas, but also 20% restored areas, and green infrastructure across Europe. Note that feature distributions consisted in continuous values, therefore, the value of each planning unit consisted in effective area, that is the planning unit size (1km²) x the suitability score.

For species and habitats, we assign area targets that aim to reduce extinction risk based on IUCN Red List criteria, inspired by previous studies (Fastré et al., 2021; Jung et al., 2021a). For species and habitats that are threatened (VU/EN/CR status in the IUCN red list) or in unfavourable conservation status (U1 and U2), the target is to protect 100% of their total distribution. This is inspired by the Favourable Reference Range values for species in unfavourable conservation status for mammals, amphibians and reptiles) which are at least equal to their current range size (D'Alessio, Davoli, et al., 2025; Davoli et al., 2025). We did not use Favourable Reference Values directly for species area targets (Davoli et al., 2025), since they are only known for 245 mammals, reptiles and amphibians species listed in Article 17, which is only a subset of all species

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considered in T7.3.

For other species and habitats, we formulate the target to minimise the distance to extinction risk or ecosystem collapse, respectively, according to IUCN Red List criteria:

- For species, we used criteria defined in the IUCN Red List of species, building on previous work (Fastre et al., 2019; Jung et al., 2021). Criterion A specifies that R_s (the total range size of species *s*) should not decline by more than 20% within a 50-year period. Therefore, the area target for species is: $t_s = 0.8\ R_s$.
- For habitats, we used the IUCN Red List of Ecosystems criteria (Keith et al., 2013, 2022). Criterion A specifies that the geographic distribution of a habitat – R_h - should not decline by more than 30% within a 50-year period. Therefore, the area target for habitats is: $t_h = 0.7\ R_h$.

For each NCP, the area target is to secure the top 50% highest value areas for each NCP, in order to maximize co-benefits for both nature and people (in the variants where NCP are included as biodiversity features).

2.3.3. Overview of scenario variants

Different planning assumptions and preferences can lead to different priority areas and outcomes. We designed scenario variants that were directly informed by engaging with stakeholders involved in implementing the EU Nature Directives and the EU Biodiversity Strategy (stakeholders were composed of policy-makers and practitioners from national agencies and delegates from EU Member States, the European Commission DG Environment, and NGOs). Discussions and workshops with stakeholders (e.g. through the Natura 2000 Biogeographical Seminar process) highlighted several planning criteria for conservation and restoration for which there was no clear consensus among stakeholders. These included: the spatial scale at which area targets should be achieved (national, biogeographical or pan-European level); whether prioritisation should focus on current biodiversity distributions or also account for potential future distributions under climate change; whether connectivity should be prioritised by protecting critical corridors and avoiding fragmented habitats, or whether planning should focus primarily on preserving core habitat patches; which values of nature (intrinsic, regulating or non-material) should be prioritised for conservation and restoration; and whether areas with high opportunity costs should be avoided to minimise potential negative impacts on production activities, or whether prioritisation should

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focus solely on ecological benefits. Building on the stakeholder process, we developed 144 TEN-N variants by testing all combinations of these planning criteria and parameter choices (Table 3), with some variants considered baseline protection scenarios and others to expand in complexity. This variant design allowed us to assess how alternative planning assumptions influence spatial priorities, and to identify consensus priorities that are consistently selected across variants. We also evaluate synergies and trade-offs among scenario variants in terms of performance for a range of ecological, structural and socio-economic indicators.

The variants were based on the following objectives and variations (Table 3):

- **Baseline protected areas** for 30% (Natura 2000 only; All protected areas) (x2)
- **Climate**: Prioritise climate-resilient areas or focus on current climate suitability (x2)
- **Connectivity:** Prioritise critical corridors and avoid fragmented habitats, or prioritise core habitat patches (x2)
- **Socio-economic costs**: Avoid high opportunity costs, or ignore costs to focus solely on benefits for biodiversity and NCP (x2)
- **NFF**: Variation of nature value preferences, and land use change scenarios (x3)
- **Area sharing** for countries, bioregions, or no sharing constraints (x3)

Table 3: Overview of the scenario variants.

Variation	Key parameter	Description
Protected areas	Manual bounded constraints	Protected areas used as baseline for the 30% (Natura 2000 only or all protected areas). Natura 2000 only, vs. all designations (including Natura 2000 plus all national designations).
Climate resilience	Linear penalty (negative penalty score)	Areas unimportant for climate refugia or climate resilience are penalised, creating a variant that incorporates these aspects.
Connectivity	Features (one per functional archetype)	Variant that includes the probability of functional connectivity and the structural fragmentation metric into the prioritisation for the 30%, using outputs from T6.3. Connectivity is always included in the rank map for green infrastructure.

Socio-economic costs	Linear penalty (positive penalty score)	Create variants of the TEN-N with or without costs, using outputs from T4.1.
Nature Futures Framework (NFF)	Lower and upper bounds of land available for restoration outside of protected areas is determined by plausible future land use. Feature weights, in line with each NFF scenario narrative.	Different realised variants for the NFF (one for each NFF corner, e.g. Nature for Nature, Nature for Culture, Nature for Society). Each of the NFF land use change scenarios (Venier-Cambron et al., 2025) determine the opportunities and constraints for restoration or de-intensification of land-use within a planning unit. We vary the weight given to certain groups of features in the prioritisation: species, habitats, connectivity, cultural NCP and regulating NCP, such that they match the three Nature Futures Framework alternatives (see section 3.5.)
Area sharing	Linear constraints	Added constraints for equal area sharing of conservation and restoration area between i) countries, or ii) biogeographic regions, or iii) no burden sharing (i.e. allocate areas freely in Europe).

2.3.4. Area sharing among countries and biogeographic regions

2.3.4.1. Area sharing constraints for the 30% conservation area target

Top priorities for protected area expansion are designed to complement existing protected areas and to close conservation gaps by minimizing target shortfall for all features.

To explore spatial priorities that balance biodiversity benefits with equitable area sharing between European countries and biogeographical regions, we created three scenario variants:

- A first set achieves 30% at the level of countries, in accordance with most national conservation strategies that aim to reach 30% at a national level. Because some countries (such as Bulgaria, Slovenia, Croatia) already reached 30% of protected area coverage, we allow for flexible sharing of area such that each country may achieve between 25% and 30% of their land area, to achieve a total of 30% area for conservation at the European level.

- A second set achieves 30% at the level of biogeographical regions, in accordance with EU policy guidance. Similarly to the country area shares, some biogeographical regions

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(Alpine, Macaronesia) are already above 30% of protected area coverage, thus we allow for flexible sharing of area such that each region may achieve between 25% and 30% of the total regional area, to achieve 30% at the European level. Our analyses showed that capping each biogeographical region at 30% performed poorly for species and habitats because some regions - Alpine, Macaronesia, Mediterranean - are already beyond or very close to 30%, but still have exceptional value for European biodiversity and high levels of coverage gaps remain for species and habitats in those regions.

- In a third set of scenarios, we identify optimal priorities that ensure 30% is achieved at the level of the EU, but without further constraints on area shares at the level of countries or regions. Although less realistic than the other two, this type of scenario enables to quantify the optimal gains under less constraints as a point of comparison and may be relevant for countries or regions that are already at 30% or above, but would have the capacity to protect more.

2.3.4.2. Area sharing for the 10% strict protection

Some countries may designate more, or less, than 10% of their area for strict protection. This was confirmed by stakeholders and Member States' representatives. For example, Sweden has pledged over 10% of strictly protected area coverage. However, some countries (e.g. France) already have interpreted the 10% as a national target in their own national strategies (namely 'strong' protection). Hence, we explore three different area sharing scenarios for the 10%, in line with the area sharing scenarios for the 30% (i.e. national area sharing for 10% will be identified within the priorities for national area sharing for the 30% conservation, etc.). We implement a flexible area sharing approach in the strict protection prioritisation, with a maximum of 15% per country, or region, to allow some flexibility. We explore three sets of variant scenarios for sharing strict protection area between countries and regions:

- A first set distributes the 10% at the level of countries, however because the 10% is a European-wide area target in the EU Biodiversity Strategy for 2030, and countries may designate more than 10% of area as strictly protected (e.g. Sweden), we allow up to 15% of area per country to be selected for strict protection in this variant.

- A second set distributes strict protection between biogeographical regions, such that each biogeographical region may have up to 15% of area selected for strict protection.

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- A third set of variants identifies optimal priorities that ensure 10% is achieved at the level of the EU, but without further constraints on area shares at the level of countries or regions.

2.3.4.3. Area sharing for 20% restoration

Unlike the 30% target, there is no official policy recommendation on how to distribute restoration areas between European countries and biogeographical regions. Therefore, in line with the prioritisation for 30% and 10%, we explore alternative area sharing scenario variants for restoration with flexible area shares for 20% restoration across Europe:

- In the scenarios ensuring country-level sharing of area allocated to conservation and restoration, as for strict protection (see above), we allow flexible sharing for restoration, so that up to 30% of each country area may be restored, while achieving 20% of restored ecosystems at the European scale. We balance the total area allocated for both restoration and strict protection in each country such that the area budget for restoration per country is equal to 30% of the country area minus the amount of area selected as priority for strict protection in that country.

- In the scenarios ensuring biogeographical regional level sharing of area allocated to conservation and restoration, as for strict protection (see above), we allow flexible sharing for restoration, so that up to 30% of each biogeographical region may be restored, while achieving 20% of restored ecosystems at the European scale. We balance the total area allocated for both restoration and strict protection between biogeographical regions so that the area budget for restoration per region is equal to 30% of the biogeographical region's area minus the amount of area selected as priority for strict protection in that region.

- A third set of variants identifies optimal priorities that ensures 20% of area is restored at the level of the EU, but without further constraints on area shares at the level of countries or regions. This variant is likely to be highly relevant ecologically as there is strong variation in the levels of ecological degradation across different countries in Europe, thus the 20% priorities for restoration should be targeted in the areas that would be most beneficial for biodiversity.

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2.3.5. Additional variations under the Nature Futures Framework scenarios

2.3.5.1. Nature for Nature

Here, the focus is on the intrinsic value of all biodiversity, with the aim to enhance natural processes (e.g. unrestricted movement and interactions), and protect and restore self-sustaining ecosystems in the absence of human needs or influence. All species and habitats are included, as well as carbon stocks as they tend to indicate ecosystems of high biodiversity value (Kujala et al., in preparation). In total, 1620 features are considered in the Nature for Nature prioritisation, including: 21 coastal habitats, 40 forests, 10 freshwater habitats, 37 grasslands, 446 invertebrates, 11 littoral habitats, 187 plants, seed dispersal, carbon stocks, 35 scrub and tundra habitats, 26 bare/sparse vegetation habitats, 773 vertebrates, 20 wetlands. Weights are defined as follows: i) higher weight to threatened and U1/U2 species (1-5); ii) species are upweighted based on trophic importance; iii) carbon stocks and carbon-rich ecosystems are assigned a weight of 10, as they are associated with higher biodiversity and are a key feature of policy interest in EU policy guidance. Socio-economic costs (when considered) are included with a small penalty value of 0.001. In the Nature for Nature scenario, we additionally upweight species of trophic importance. Trophic importance is calculated for terrestrial vertebrate species as a composite index that combines species trophic level, betweenness centrality, and trophic distinctiveness, based on the metaweb summarizing all trophic interactions between European vertebrate species (Maiorano et al., 2020). This index ranges from 0 (low importance) to 3 (high importance); we multiply species weights in the Nature for Nature scenarios with a factor of (1 + trophic_importance). For the 10% in the Nature for Nature perspective, the same features are included except 19 habitat types that are known to be dependent on sustained agricultural practices (Halada et al., 2011). The weights of keystone apex predators and ecosystem engineer species are further multiplied with a factor of 10. Further, areas of low ecological integrity and low trophic complexity are avoided. Strictly protected areas are designed in a buffer/core spatial structure such that 10% expansion are predominantly located in the core of a larger patch of protected areas within the 30%. For restoration in the Nature for Nature perspective, land use transitions are informed by the Nature for Nature land use change scenario from WP5. For green infrastructure in the Nature for Nature perspective, the main focus is on connectivity which is assigned a high weight, as well as all remaining habitats and species that are not fully covered as part of the area selected for conservation or restoration, while NCP are given a small weight of 1.

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2.3.5.2. Nature for Society

The Nature for Society scenario focuses on maintaining and enhancing benefits from biodiversity to society, people and the economy, with the idea that conservation and restoration efforts should support human well-being and minimise socio-economic conflicts with productive activities. The Nature for Society prioritisations for conservation and restoration focus on regulating NCP and species and habitats that provide regulating services. In total, the Nature for Society scenario considered 1066 features: 10 regulating NCP, 40 forest habitats, 3 grassland habitats, 96 invertebrates (pollinators), 10 littoral biogenic habitats, 187 plants (autotrophy), 4 scrub & tundra habitats, 599 vertebrates providing regulating NCP (O'Connor et al., 2026), and 13 wetland habitats. Carbon-rich ecosystems (saltmarshes, fens, mires, bogs, peatlands) and riparian habitats (riparian and alluvial forests) were upweighted with a factor of 80 as they provide NCP such as carbon storage and sequestration, water quality regulation, and flood mitigation. Regulating NCP layers (carbon stocks, carbon sequestration, pollination, soil retention, and regulating species-based services) are each assigned a high weight such that their combined weight is equal to the combined weight of species and habitats. Socio-economic costs (when considered) are included with a high penalty value of 0.1. For the 10%, the same features are included except agricultural pest control (assuming that agricultural activities are not allowed within strictly protected areas, in line with the IUCN protected area management categories I and II used as the baseline), and weights for carbon stocks and carbon-rich ecosystems are doubled as they require non-disturbance to function as carbon sinks. Strictly protected areas avoid areas of high opportunity costs (as for the 30%), and are designed in a buffer/core spatial structure to avoid further conflicts with human activities. For the 20% restoration, the transitions are informed by the Nature for Society land use change scenario from WP5 (see D5.2, (Venier-Cambron et al., 2025)). For green infrastructure, regulating NCP are assigned a high weight of 1000 such that they have equal importance as connectivity, species and habitats.

2.3.5.3. Nature as Culture

The Nature as Culture scenarios focused on the relational value of nature to people and the cultural importance of species and habitats. Under this paradigm, conservation and restoration focuses on species and ecosystems that support people's sense of place, sense of identity, access to nature for learning, inspiration and traditions, psychological and physical experiences in nature, as well as other non-material benefits (Díaz et al., 2018). In practice, the prioritisations under the Nature as Culture scenario prioritized species and habitats of cultural importance, and

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cultural services (nature recreation, and cultural species-based services). In total, the Nature as Culture scenario considered specifically 1551 features: 9 cultural NCP, species associated with cultural importance such as for medicinal plants and wildlife watching (O'Connor et al., 2026), species and habitats listed in the Birds and Habitats Directives and species endemic to Europe (supporting identities). Cultural NCP layers are each assigned a high weight, such that their combined weight is equal to the combined weight of species and habitats included. Socio-economic costs (when considered) are included with an intermediate penalty value of 0.01. For the 10% strict protection, the focus is on avoiding extinctions of threatened species and habitats (including vulnerable species and habitats occurring in human-dominated landscapes) as well as all cultural NCP and species and habitats of cultural importance. For the 20% restoration, the same set of species, habitats and NCP as for the 30% are included. The restoration transitions are informed by the NaturaConnect land-use change estimates (Venier-Cambron et al., 2025). For green infrastructure, cultural NCP are assigned a high weight of 1000.

2.4. Stakeholder validation and engagement

Systematic conservation planning (SCP) solutions are meant to inform policy and implementation, and it is thus critical that they are fit for purpose and do not mis-represent data. Continuous stakeholder engagement and involvement along the SCP process can help to validate, check and improve the prioritization outputs.

For WP7 of the NaturaConnect project we conducted a range of different engagement events both in-person and online (see Table 4 & Figure 4). Target stakeholder groups for engagement included EU Member States representatives, NADEG representatives and other actors involved in the Biogeographical Seminars process, environmental departments and conservation authorities, national and regional planning authorities, EU Commissions (DG Environment, DG Regional and Urban Policy), European Environment Agency, and conservation NGOs (IUCN-Europe), the European Network of Heads of Nature Conservation Agencies (ENCA), and the European council of spatial planners (ECTP). See Schnepf *et al.* for a full overview of stakeholder engagements in NaturaConnect (Schnepf et al., 2024).

The overarching purpose for stakeholder engagement was to establish collaborations with these key stakeholders and receive detailed feedback on the founding elements for the TEN-N network design, ground truth the results and elicit feedback on included data, targets, weights, constraints, details of relevant scenarios, and views on implications of the preliminary results. The

engagements ensured that the ongoing work was relevant in scope, understandable, accessible and timely, and that scenarios developed were useful for the specific policy contexts of different stakeholders. In addition to the model results and shaping of analysis and scenarios, interactive feedback software was developed and utilised during selected online engagements to elicit stakeholder feedback in a structured and spatial-explicit way (described in D8.2 (Jung et al., 2026)).

Table 4 outlines the stakeholder engagement undertaken as part of this deliverable.

Table 4: Stakeholder engagement undertaken for WP7

Title of stakeholder engagement	Date	Location and type	Number and main stakeholder groups engaged	Aims of engagement for WP7
NADEG Biogeographical seminar survey	07/2023 -> 09/2023	Online survey	12; stakeholder groups not known (anonymous survey responses)	**Aim:** Identify preferences and relative importance of input data and possible scenarios for the TEN-N analysis
NaturaConnect First Stakeholder Engagement Event	28/02/2023	Brussel (BE), World Café (in-person event)	44; main stakeholder groups engaged: • National governmental administrations/authorities • EU institutions or EC • Research institutes or universities • International institutions • NGOs/CSOs	**Aim:** First in-person meeting with relevant stakeholder groups, understand their constraints and needs
NaturaConnect: Designing Nature Futures scenarios to support a Trans-European Nature Network	8-10/05/2023	Leipzig (DE), Workshop (in-person event)	13; main stakeholder groups engaged: • National governmental administrations/authorities • EU institutions or EC • Local governmental administration/authority • Sub-national governmental administration/authority • Research institutes or universities • NGOs/CSOs	**Aim:** Elicit stakeholder feedback on TEN-N planning priorities with regards to prioritizing natures values: species, habitats, threatened species and habitats,

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			• Private company/sector	regulating NCP, cultural NCP
Biogeographic Seminars, organised by the European Commission DG Environment as the 4th Natura2000 Biogeographic process : We took part in the Biogeographic seminars for all regions: Atlantic, Boreal, Mediterranean, Continental & Alpine, Macaronesia (2023-2024).	09/2023, 10/2023, 11/2023, 04/2024, 06/2024	Hannover (Germany) ; Helsinki (Finland) ; Larnaca (Cyprus) ; Açores (Portugal) ; Prague (Czech Republic). We gave presentations, collected stakeholder input via menti questionnaires, took part in workshops and breakout group discussions, animated a booth for NaturaConnect.	>200; main stakeholder groups engaged: • EU Commission DG ENV • NADEG members • NGOs • Planning authorities • National ministries • Park managers	**Aim**: Understanding stakeholder constraints and needs. Elicit stakeholder feedback on prioritisation objectives and methods, planning criteria, weighting of biodiversity features, consideration of climate change resilience
NaturaConnect: Mapping the Future of Europe's Protected Areas - Setting Priorities for Strategic Expansion	22/05/2025	Online (webinar)	68; main stakeholder groups engaged: • NGOs • Planning authorities • Park managers • Conservation scientists	**Aim:** Elicit spatially explicit feedback on methods and results regarding spatial priorities for conservation to validate and refine methods, input data and constraints.
NaturaConnect: From Science to Action: Strategic Planning for the Trans-European Nature Network (TEN-N)	20-21/01/2026	Brussels (BE), Event (in-person workshop)	33; main stakeholder groups engaged: • EU Commission • NGOs • Planning authorities • National ministries • Park managers • Conservation scientists	**Aim:** elicit spatially explicit feedback on methods and results regarding spatial priorities for conservation and strict protection. Understand stakeholder needs and discuss avenues for uptake

				and implementation.
NaturaConnect: Providing feedback on priority areas for implementing European area-based biodiversity targets	17/03/2026	Online (webinar)	44; main stakeholder groups engaged: • NGOs • Planning authorities • Park managers • Conservation scientists	**Aim:** elicit spatially explicit feedback on spatial priorities for conservation, strict protection and restoration.
EUROPARC Federation Siggen Seminar on planning and implementing restoration measures in protected areas	18/03/2026	Online (webinar)	122 participants: main stakeholder groups engaged: • Park managers • NGOs • National authorities	**Aim:** inform stakeholders and communicate on the methodology and first results on identifying spatial priorities for ecological restoration in Europe.
France workshops: Case study France workshop with stakeholders, and Models and approaches for conserving biodiversity today and tomorrow	05.2024 and 11.2025	Paris (France), Muséum National d'Histoire Naturelle In-person workshop	National and regional authorities and experts (including from PatriNat, the Office Français de la Biodiversité, and departmental and regional authorities).	**Aim:** elicit stakeholder feedback on biodiversity features, prioritisation methods and results, discuss integration of European and national priorities for conservation and strict protection.
Bilateral engagement	Throughout project duration	In person and online Hybrid	Main stakeholder groups engaged: • Representatives of planning authorities (e.g. Latvia, Greece) • NGOs (e.g. WWF-CEE)	**Aim:** Discuss and compare national-level approach for designating protected areas, with European wide

				prioritisation analyses.

These engagements and the contributions and inputs of stakeholders played a critical role in shaping, refining and validating the underlying data, methods and results of D7.2. A summary of how stakeholder input informed and was integrated into the analysis of D7.2 is outlined in Figure 4.

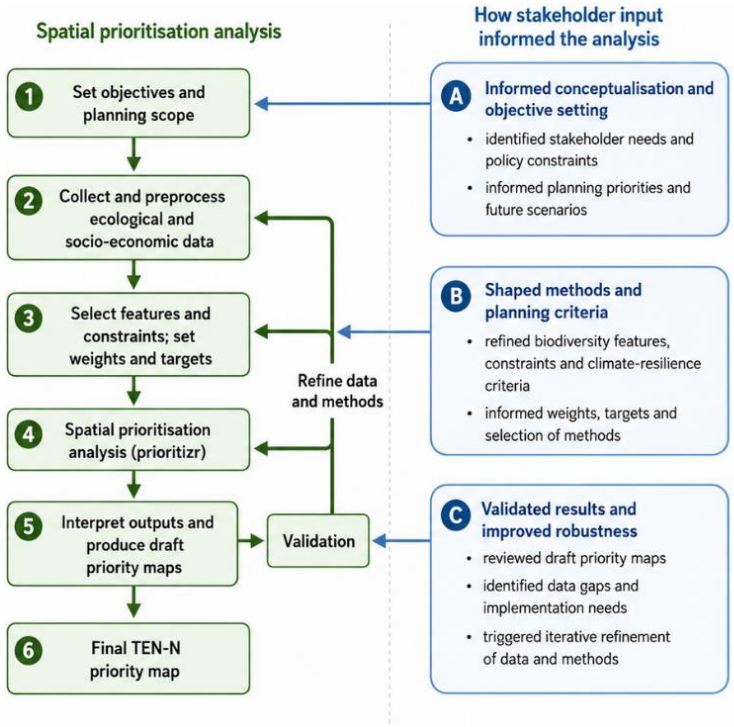

Figure 4: Stakeholder engagement throughout the spatial prioritisation workflow.
Figure design: Louise O'Connor; layout: AI-generated.

2.5. Consensus mapping or 'safe bet' areas

To identify consensus priorities, we first map the selection frequency by averaging the prioritisation outputs across all variants, for each objective and for each protected area baseline (for area consistency). This produced a selection frequency score per planning unit, ranging from 0 to 1, where 0 indicates that the planning unit was never selected across variants and 1 indicates that it was always fully selected as a priority. We then applied an objective-specific threshold values to delineate consensus priority areas corresponding to the target coverage for each objective: 30% of land for conservation, 10% for strict protection and 20% for restoration. To ensure consistency in the baseline protected-area layer, consensus priorities were derived

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separately for variants using all existing protected areas as the baseline, versus those using Natura2000 sites only as the baseline. In this deliverable, we report consensus priorities for variants using all existing protected areas as the baseline (as it is more realistic that most or all existing nationally-designated protected areas will count towards 30% that only Natura 2000 sites). Finally, we evaluated the performance on the consensus solution, across a range of ecological, structural and socio-economic indicators.

2.6. Evaluating the performance of the TEN-N variants

Indicators are crucial for tracking progress towards the EU Biodiversity Strategy for 2030 and evaluating the performance of the TEN-N. While traditional indicators that quantify the percentage of protected land area are useful for assessing general trends in the expansion of protected area (PA) networks, they provide little insight into the quality of protected areas for conserving biodiversity and maintaining important ecological processes. We developed a comprehensive set of indicators to assess the performance of the TEN-N. These performance indicators track various ecological, structural, and socio-economic metrics, generate insights into the quality of the existing PA network, and contextualise gains in performance that could be achieved by implementing the TEN-N (Brumm et al., 2026).

In addition to protecting an adequate amount of land area, a truly coherent TEN-N must be comprehensive, adequate, resilient, and effective (CARE principles). Because the identification of expansion priorities is influenced by various input parameters – including the formulation of constraints (e.g., area sharing), inclusion of conservation features (e.g., priority species and habitats; NCP), and the addition of penalties (e.g., climate; connectivity) – trade-offs are an inherent characteristic of the systematic conservation planning process. Therefore, evaluating the performance of the TEN-N requires the development of a complementary set of performance indicators tailored to align with the CARE principles.

Comprehensiveness

Assessing the extent to which distributions of priority species and habitats are protected can be achieved using indicators such as mean representation or mean target achievement (MTA (Jantke et al., 2019). The MTA has been identified as a potential indicator informing EU BDS Sub targets 1.3 and 1.4 (Joelson et al., 2026). Here, we have developed novel variants of the MTA to assess comprehensiveness across Europe and to enable normalization by biogeographic region

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and country. This version of the MTA, intermediate target achievement values for each conservation feature may also be exported to allow for more detailed assessments, such as characterizing the extent to which feature- and region-specific target achievements contribute to overall estimates of MTA across Europe. Additional options include the flexibility to aggregate MTA calculations by taxonomic or habitat group, or by using different partitions of policy relevance (e.g., Article 17 habitats; IUCN Red List species).

Adequacy

To achieve the ambitious targets of the Kunming-Montreal Global Biodiversity Framework and meet the legal commitments of the EU Biodiversity Strategy for 2030, protected area networks must expand to cover at least 30% of total land area. While protected land area is a fundamental indicator for assessing the adequacy of protected area networks, additional metrics are needed to monitor changes in the average size of individual protected areas. Because larger protected areas can help insulate species and habitats against landscape pressures, reporting on the size of protected areas would help in monitoring progress towards a more adequate TEN-N (Beher & Visconti, 2026). Accordingly, we quantify both the total extent of protected land and the mean size of protected areas across Europe and within individual biogeographical regions and countries (i.e., contributing to assessments of responsibility sharing) (Eckert et al., 2023).

Resilience

To sustain biodiversity and maintain conservation relevance, protected area networks must be designed to support fundamental ecological processes and account for shifts in species distributions and habitat suitability under climate change. Here, we assess the degree of connectivity among protected areas by calculating dispersal-based estimates of absolute (ProtConn) and relative (RelConn) protected and connected area (Godínez-Gómez et al., 2026). To improve the ecological basis of such estimates, we assume a median dispersal distance of 10 km and use the inverse maximum probability-weighted effective mesh size calculated among EUNIS habitat types as a proxy of landscape resistance (Dertien et al., 2025; Moreira et al., 2024; Poulsen et al., 2025; Prima et al., 2024). Further information on the connectivity metrics is provided in Dertien et al., 2025.

Resilience of protected area networks can also be approximated by estimating the extent to which the adaptive potential of species is protected, and such estimates may be derived using prioritization techniques that account for species-specific sensitivities under current and future

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climatic conditions. To develop an indicator of climate resilience, we first extracted the top decile of scores from the priority rank map created by Cavalcante *et al.* and then quantified proportional overlap both with existing protected areas and expansion priorities (Cavalcante et al., 2025b).

Efficiency

In addition to these ecological considerations, protected area network expansions should attempt to minimize opportunity costs associated with foregone economic benefits that would otherwise be generated by agricultural, pastoral, or forestry production sectors (Spencer et al., 2025). Therefore, we also quantify sector-specific opportunity costs associated with TEN-N expansion priorities to characterize potential socio-economic-ecological trade-offs and assess aspects of network efficiency and effectiveness.

In summary, we considered the following performance indicators to evaluate the benefits of top priorities for protected area expansion, strict protection and restoration, covering each dimension of the CARE principles (Kukkala & Moilanen, 2013; Linke et al., 2011):

- Structural/Spatial indicators:
    - % transboundary areas selected as top priorities
    - connectivity (ProtConn)
- Biodiversity benefits :
    - Average representation of species (% distributions)
    - Average representation of habitats (% distributions)
    - Top 10% climate-resilient areas for biodiversity selected (%)
    - Irreplaceability (%)
    - Top 10% areas of high ecological integrity selected (%) (for strict protection only)
- Benefits to people
    - Carbon stocks and carbon sequestration potential selected (% distributions)
    - Average representation of cultural NCP (% distributions)
    - Average representation of regulating NCP (% distributions)
- Feasibility
    - new designation vs. upgrade of existing non-strict PA or (strict only) (%)
    - new designation vs. enlarging existing PA (30%) (%)
    - socio-economic opportunity costs (€/ha)

Each indicator is described as individual factsheet online (Brumm et al., 2026).

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Visualizing the performance of planning solutions

To compare the performance between the expansion priorities and existing protected areas, we created circular barplots in which individual axes correspond to specific performance indicators. Inner bars were shaded grey to reflect the performance of existing protected areas, with performance indicators expressed as percentages with values ranging from 0% to 100%. Extending from the outer edge of each bar, we plotted an additional colored bar corresponding to the performance of the proposed consensus solution (i.e., existing protected areas and expansion priorities).

2.7. Methodology for scoping for Key Biodiversity Areas aligned with Prioritization results

Key Biodiversity Area (KBA) criteria identify a site as a KBA based on the percentage of the global population of a species at a site. If above a certain threshold (which varies by criterion) then the site meets global KBA status. Some sites that do not meet these criteria but are recognised as important sites and contained within the World Database of KBAs are identified as regional KBAs. This includes Important Bird and Biodiversity Areas (IBAs) which are recognised in EU legislation. At present only 22% of KBAs in Europe are considered as global KBAs in the World Database of KBAs.

The species distribution layers collated and developed for NaturaConnect are European in scope, and as such are not suitable to evaluate sites for their KBA potential. We therefore adopted the IUCN Red List of Threatened Species as the reference for KBA scoping because the species assessed on this list contain maps of their global extent.

2.7.1. The KBA Secretariat Scoping Tool

The KBA Secretariat, based in Cambridge UK, has developed a KBA Scoping Tool (KBA Partnership, 2025). This tool uses data from the IUCN Red List of Threatened Species (IUCN Red List – IUCN 2025) for all species that have a range map of their distribution (92,255 species; including terrestrial, freshwater, marine and subterranean species). Area of Habitat (AOH) maps are calculated for each species based on data in the IUCN Red List account of the habitats the species uses as well as its altitudinal distribution limits and its distribution map (Brooks et al., 2019). The AOH and range map data are then incorporated into an Assessment Parameter

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Database (APDB) across a grid of hexagonal cells at 2.5 km intervals, by calculating the area of range and AOH for each species within each cell. The KBA scoping tool takes a GIS polygon of one or more sites and will query each site to obtain the sum and percentage of the area of each species' range and AoH within the site from the intersecting hexagon cells and the global range or AOH for each species. The KBA Scoping Tool identifies potential species that qualify a site as a KBA by assessing the percentage of the global range and AOH at a site with the thresholds in the various KBA criteria. As an output it provides a list of sites which may be potential KBAs with the KBA criteria potentially triggered, as well as a list of species that may occur at each site with those that may qualify the site as a KBA. The criteria considered include A1 (threatened species on the IUCN Red List – different percentage thresholds occur for CR/EN species and VU species – subcriteria A1a-e), B1 (geographically restricted single species), B2 (restricted-range species in a taxonomic group) and B3 (ecoregion or bioregion restricted species). The KBA scoping tool only identifies sites as potentially qualifying as KBAs. In order to be recognized and published as a KBA in the WDKBA, there must also be relatively recent confirmation the species is present at the site and that sufficient reproductive units of the species are present to allow maintenance of the population (the number varies according to the KBA criterion). A KBA proposer can therefore use the outputs of the tool to develop a shortlist of species to assess and then look for supporting information to confirm that the species is present within the site and there are sufficient reproductive units to qualify the site as a KBA. The analyses in this report have not confirmed this additional information and therefore only identify potential KBAs and species that potentially qualify them.

2.7.2. Scoping of KBA potential across Europe

This analysis focused on the broader Europe as analysed by the NaturaConnect project, including all EU Member States plus the United Kingdom, Norway, Switzerland, Iceland, and Balkan countries. While NaturaConnect analyses primarily focused on terrestrial conservation these analyses include both terrestrial and marine for the scoping of existing KBAs and existing protected areas and the results are given for each realm separately. We made three broad analyses to identify potential KBAs across Europe as follows:

1. Scoping of existing Key Biodiversity Areas. The aim of this analysis was to identify which additional species could qualify existing sites as KBAs. We scoped the network of KBAs published in the WDKBA (September 2025).

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2. Scoping of existing protected areas and OECMs. This analysis aimed to identify which existing protected areas might qualify as KBAs. We scoped all protected areas and OECMs from the WDPCA (IUCN and UNEP-WCMC 2025). Some protected areas in Europe are already recognized as KBAs and we identified these using a union of the KBA and WDPA layers to identify those protected areas with complete KBA coverage (>98% cover).
3. Scoping of NaturaConnect output. The NaturaConnect conservation prioritization outputs identify those 1 km² grid cells that achieve the best solution given certain constraints (development pathways and climate change scenarios). A harmonized consensus output across all scenarios was provided to the KBA Secretariat by the project. We scoped this harmonized solution for cells that fall outside the existing protected area network. Specifically, we scoped the solution's 1 km² cells aggregated to 10 x 10 km cells used by the EU as a standard grid across the continent. Scoping results vary depending on the scale of 'cells': the larger a cell the more likely it will qualify as a KBA. We selected the 1 km² cells to 10x10 grid aggregate as a scale that was likely to be useful in identifying potential areas that may be KBAs outside existing protected areas and where specific sites could be delineated considering these results.

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3. Results

3.1. Blueprint for the TEN-N: Consensus top priorities for conservation, strict protection, restoration

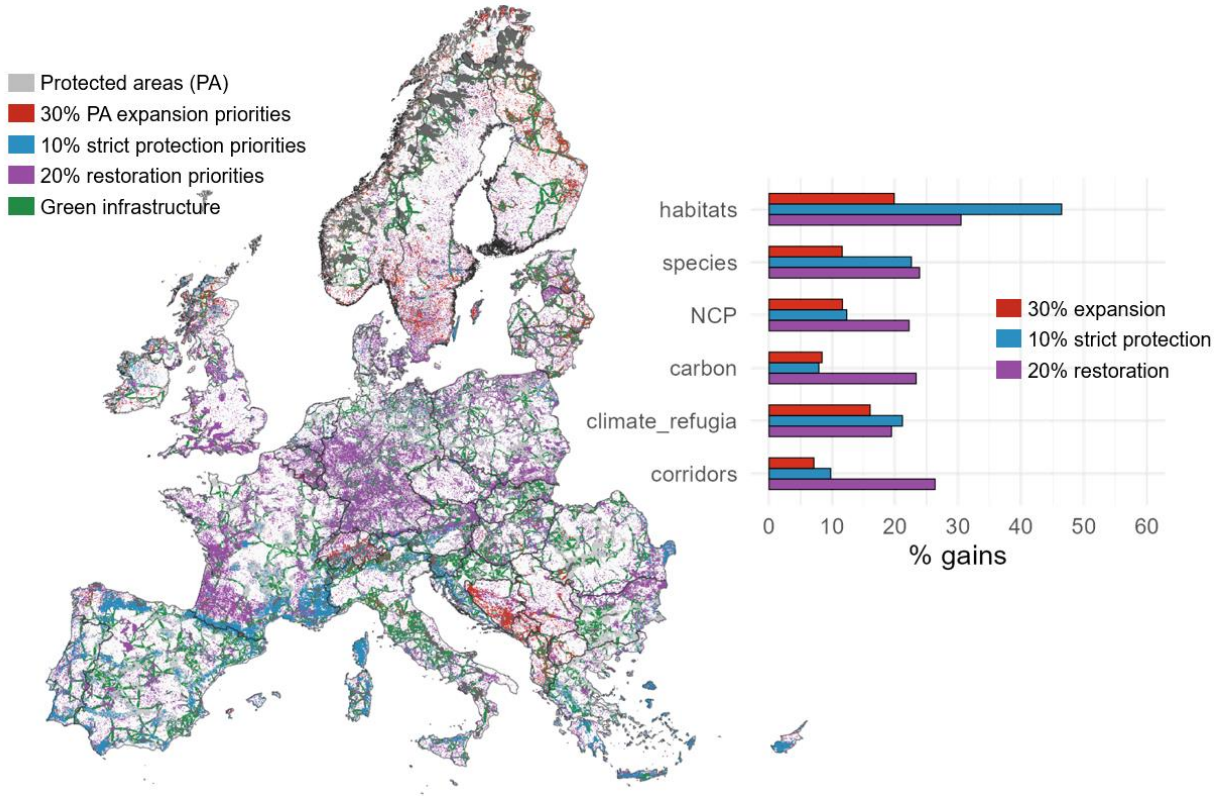

Figure 5: European-wide consensus priorities for conservation, strict protection and restoration.
The map shows the consensus priorities coloured by type: conservation, strict protection, restoration (O'Connor et al., 2026). Green infrastructure is represented as critical ecological corridors (Dertien et al., 2025). Existing protected areas not otherwise selected as a priority for restoration or strict protection upgrade are shown in grey. The barplot the gains of protection and restoration within the top priority areas identified, measured in percentage points across indicators, coloured by objective: protected area expansion priorities for 30% (red) covering 5% of European land area; priorities for 10% strict protection (blue) covering 6% of European land area; and restoration priorities (purple) covering 20% of European land area.

Priorities for protected area expansion to reach 30% land protected. Top priorities for protected area expansion represented a 5% increase in European land protected, from 25% of land currently protected to 30%. A majority of consensus priorities for 30% conservation were found in the Alpine, Mediterranean and Boreal biogeographic regions, and to a lesser extent in other biogeographic regions (Figure 5 & Figure 7). The multicriteria performance evaluation conducted for the consensus priorities revealed significant gains in performance that could be

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achieved relative to that of the existing network of protected areas across Europe. We found that expanding protection by just 5% of land in consensus priorities to reach 30% of protected land across Europe (closing the gaps in biodiversity coverage) would result in substantial gains in representativeness of species, habitats and NCP and in the resilience and connectivity of European protected areas (Figure 5). The representation of habitats increased from 49% in current protected areas to 69% with expansion priorities, and representation of species increased from 33% to 45%. The representation of key areas for nature's contributions to people increased from 25% to 36%, and representation of ecosystems with high carbon storage and sequestration potential increased from 28% to 37%, thus securing benefits for both people and nature. The percent of protected climate resilient land area increased from 33.2% to 49%, showing improvements in long-term conservation relevance and in the conservation of areas that can support species persistence under future climate change. The expansion priorities also increased the representation of ecological corridors from 39% to 47%. On average, 55.1% of species and habitat representation targets were achieved by consensus priorities identified in the top priorities for protected area expansion, representing a substantial increase from 41.1% in current PAs (Figure 5 & *Figure 6*). In addition to increasing protections for species and habitats across Europe, our results suggest that systematic expansions of the protected area network would also support climate mitigation by increasing the total conserved carbon stock from 27.0% to 35.2% and conserving an additional 8.4% (increasing from ~30.6% to ~39.0%) of available carbon sequestration potential. Additionally, the relative connectivity indicator, which quantifies the proportion of protected land area in a region that is structurally connected, increased slightly from 7.4% to 7.8%. These findings indicate the consensus priorities are located strategically to improve the overall adequacy, representativeness, connectivity and resilience of the European PA network.

Priorities for 10% strict protection. Strict protection priorities expanded from 4% to 10%, requiring 6% of additional land area. We found that a majority of consensus priorities for strict protection are primarily located in the Alpine, Mediterranean biogeographical regions and notably in most European islands. These included a majority of non-strictly protected areas that were designated as priorities for being upgraded to strict protection. In terms of performance, the consensus priorities achieved substantially higher levels of representation relative to existing strictly protected areas. Within the top priority areas to reach 10% strict protection coverage, the representation of habitats increased from 8.0% within existing strictly protected areas to 54% with the strict protection priorities, corresponding to a 7-fold increase. Species representation increased from 4.7% to 27% (i.e., a 6-fold increase). Ecosystems of high ecological integrity were

also better represented with strict protection priorities, from 5.9% within existing strictly protected areas, to 19% with strict protection priorities, corresponding to a 3-fold increase. The strict protection priorities also increased protection of top climate-resilient areas from 6.2% to 27.4%. Furthermore, top priorities for strict protection led to an increase in mean target achievement from 5.9% to 34.5%; conserved carbon stock and sequestration potential increased by an average of 7.9%; and total network size increased from covering 4% to 10% of European land area. While RelConn decreased from 15.1% to 11.2%, absolute ProtConn increased from 0.5% to 0.9%, suggesting that systematic **strictly protected area expansions would nearly double the area of total connected and strictly protected lands in Europe**.

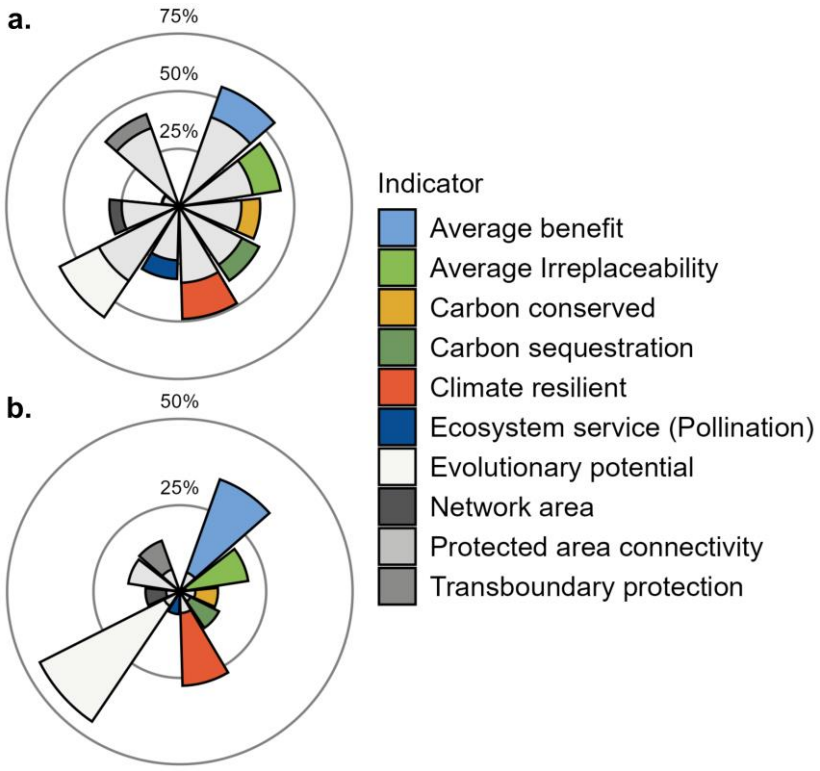

Figure 6: Performance of conservation (a) and strict (b) consensus solutions (coloured) compared to existing protected areas (grey).

As a comparison for strict protection priorities, we quantified how roadless areas compared to strict protection priorities in terms of performance, using roadless areas data for Europe recently published by Testolin et al. (2026). We found that roadless areas cover 50% more areas of high ecological integrity (here measured as a combination of low HANPP, low fragmentation, and high trophic interaction diversity among vertebrate species) than the consensus strict protection

priorities, but lead to a 2 to 3-fold lower representation for biodiversity compared with our priority map (O'Connor et al., in preparation).

Priorities for 20% restoration. Top priorities for restoration within existing protected areas that are degraded were especially located in the UK, Germany, Poland, and France. Restoration priorities outside existing protected areas are mostly located in France, Germany, Sweden, Switzerland, Bosnia and Herzegovina, Denmark, and Portugal. In terms of performance, we found that priorities for restoration could lead to substantial gains on average of the potential distributions of habitats, species, NCP and corridors to be restored. Specifically, we found that top priorities for restoration could restore in total 23.9% potential distributions for species and 30.5% for habitats, 26.4% of ecological corridors, and 23.4% of areas with high carbon stocks and carbon storage potential.

Taken together, we found that consensus priority areas for conservation, strict protection and restoration (including existing protected areas) cover 40% of European land area. When additionally overlaying ecological corridors (from Dertien et al., 2025 and Dertien et al., in preparation) that were not otherwise selected as part of restoration priorities or priorities for protected area expansion, the total area covered by one of these dimensions of the TEN-N is 50% of European land area (Figure 5).

3.2. Robustness of priorities for conservation, restoration, strict protection

Depending on the scenario variant different areas might be selected for conservation and restoration. We assessed which places are consistently selected ('safe bet' areas) and which are sensitive to certain planning criteria. We highlight which areas are only selected under particular criteria, and those considered to be 'safe bet' consensus priorities selected across scenario variants.

3.2.1. 30% conservation

We found that 26% of European land was selected as a priority for 30% conservation in at least 1 variant, whereas less than 1% of European land was selected across all variants (Figure 7), highlighting strong spatial variation among scenarios. Performance varied substantially among TEN-N variants, particularly for the representation of species and habitats, whereas variation in

the representation of NCP was comparatively smaller. For species, representation ranged from 37.6% to 47.9% across variants, compared with 58.6% to 70.7% for habitats and 30.3% to 36.0% for NCP. Thus, the variant choice had a stronger influence on the representation of species and habitats than on the representation of NCP.

The highest representation of species (47.9%) and habitats (70.7%) was achieved under EU-wide allocation without area-sharing constraints and with Nature for Nature preferences. In contrast, imposing area-sharing constraints at the biogeographical-region level and prioritising Nature for Society resulted in the lowest species representation (37.6%), while combining Nature as Culture preferences with biogeographical area sharing resulted in the lowest habitat representation (58.6%). For NCP, Nature for Society preferences produced the highest representation (36%), whereas Nature for Nature preferences resulted in the lowest (30.3%), with area-sharing constraints having comparatively little influence.

Furthermore, the consensus priorities performed close to the best-performing variants for most indicators (Figure 7). In other words, the consensus priorities approach the optimal potential performance across variants, while avoiding the need to select a particular combination of assumptions.

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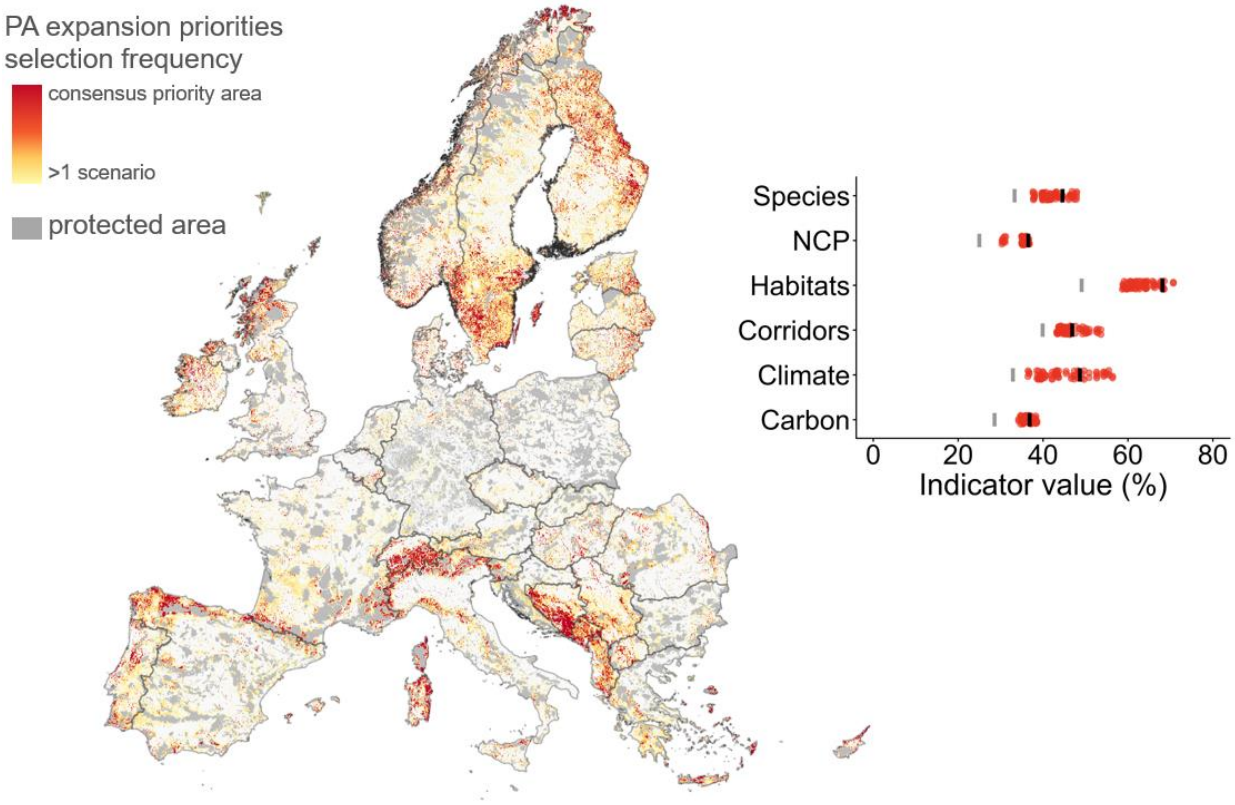

Figure 7: Selection frequency of top priorities for protected area expansion and their performance across variants. The map shows the selection frequency across variant scenarios, with darker shades indicating higher consensus among variants. The jitter plot shows the performance of the consensus priority areas for reaching 30%: each dot represents a single variant; the black line represents the performance of the consensus priorities; the gray line represents existing protected areas. Note that coloured areas might be visually overrepresented in the figure (the planning unit grain is 1 km²).

3.2.2. 10% strict protection

We found that 24 % European land was selected as top priority for strict protection in at least one variant, whereas less than 1% of European land was consistently selected across all variants, predominantly located in mountainous regions (notably in Greece, Spain and France) and on Mediterranean islands (Figure 8). There was substantial variation in the performance of different variants, especially in the representation of species, habitats and ecosystems of high ecological integrity.

Strict protection priorities that implemented EU-wide allocation without area-sharing constraints and Nature for Nature preferences led to the highest performance for the representation of species (30%), habitats (55%) and ecosystems of high integrity (31%), here defined as ecosystems of low fragmentation, low human pressure, and high trophic complexity. In contrast,

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imposing area-sharing constraints at the biogeographical-region level, minimizing socio-economic opportunity costs, and emphasizing Nature for Society values, resulted in the lowest performance for species (13% average representation), habitats (35% average representation) and ecological integrity (12%). By contrast, Nature for Society preferences paired with area sharing among biogeographical regions led to the highest gains in representation of key areas for NCP within strict protection priorities.

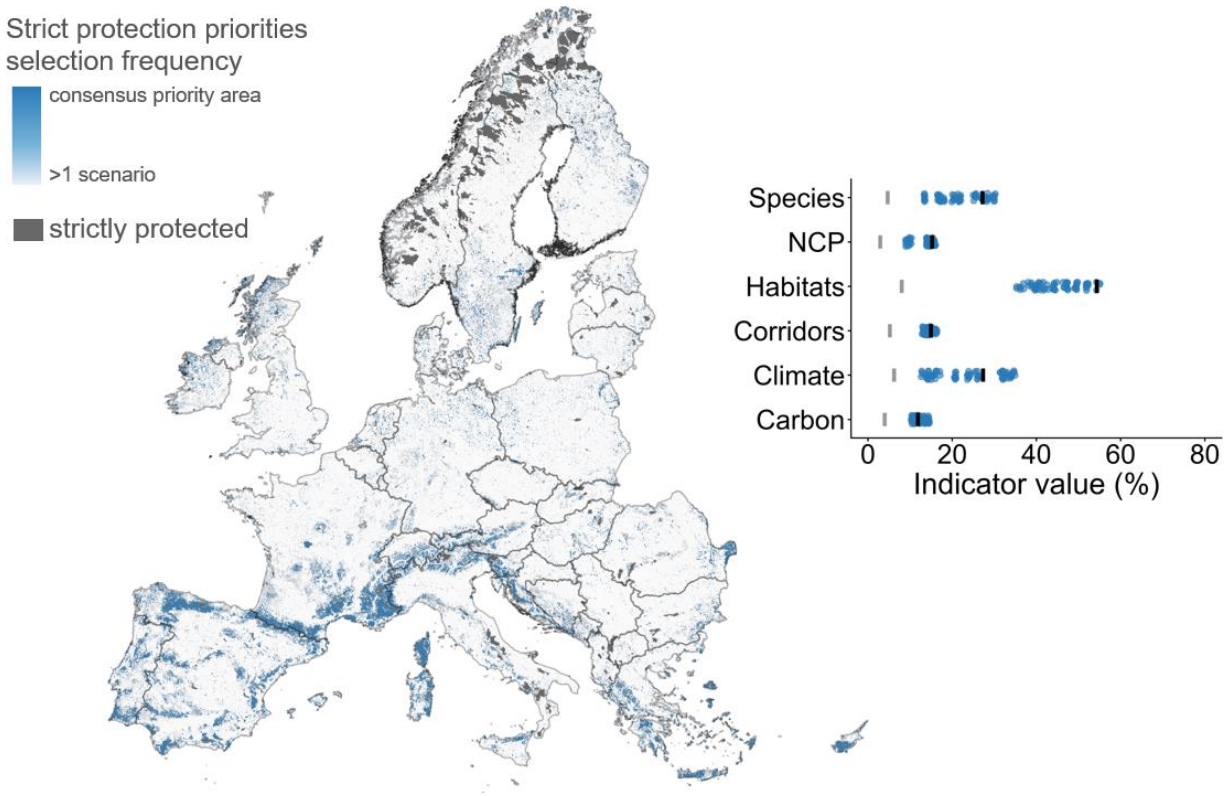

Figure 8: Selection frequency of priorities for 10% strict protection and their performance across all variants. The map shows the selection frequency, with darker shades indicating higher consensus among variants. The jitter plot shows the potential gains from the priorities compared with the current performance within existing strictly protected areas. Each dot represents a single variant; the black line represents the performance of the consensus priorities; the gray line represents existing protected areas. Note that coloured areas might be visually overrepresented in the figure (the planning unit grain is 1 km²).

3.2.3. 20% restoration

For restoration, we found that 41% of European land was selected as priority in at least 1 variant whereas 6% was consistently identified as a top priority for restoration across all variants, located throughout Europe in degraded ecosystems but notably concentrated in productive systems in

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the Atlantic biogeographic region (e.g. in southern England, in the Landes in France), in the Continental region (e.g. in Germany, Poland) and in the south of the Boreal region (Sweden, Norway) (Figure 9).

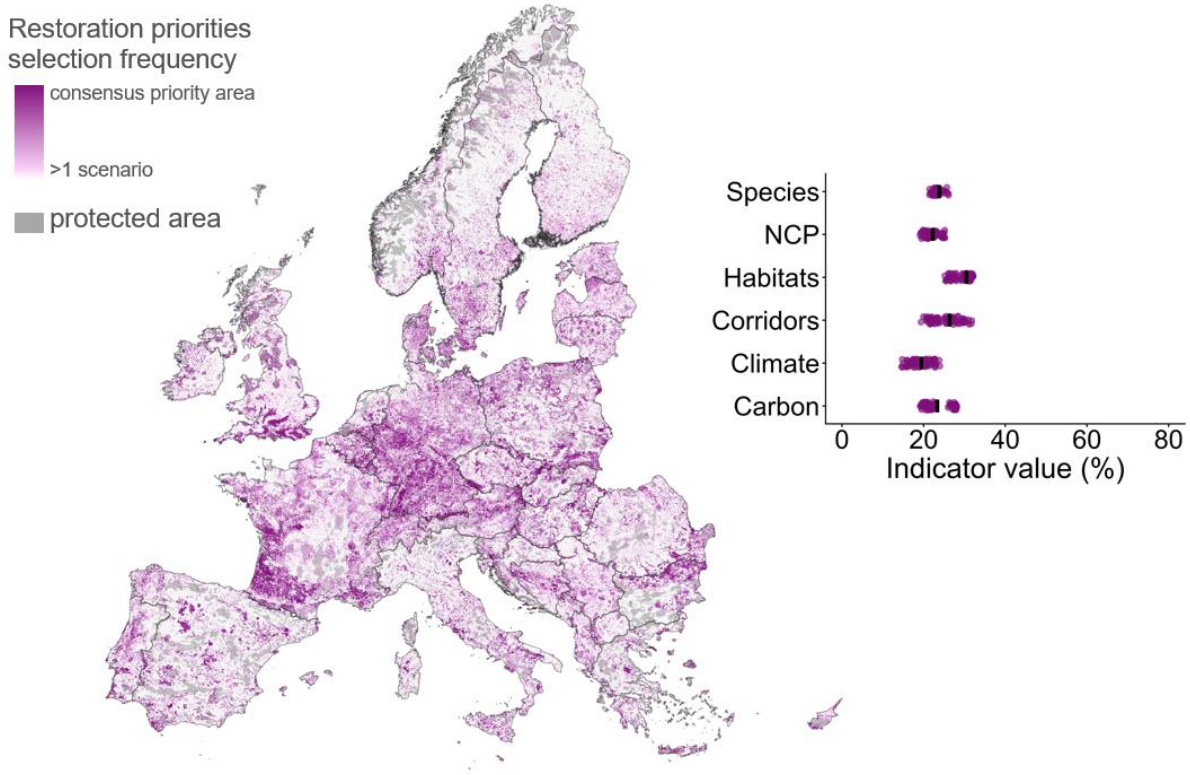

Figure 9: Selection frequency of top priorities for 20% ecological restoration and their performance across variants. The map shows the selection frequency, with darker shades indicating higher consensus among variants. The jitter plot shows the potential gains from the restoration priorities: each dot represents a single variant; the black line represents the performance of the consensus priorities. Note that coloured areas might be visually overrepresented in the figure (the planning unit grain is 1 km²).

3.3. Synergies and trade-offs between scenarios

Here we ask: what do we gain or lose under different planning criteria and assumptions? In addition to assessing the performance of existing protected areas and consensus priorities, we evaluated synergies and trade-offs between scenarios using performance indicators. More specifically, we identify areas of consensus and high uncertainty among alternative configurations of the TEN-N that vary in their relative preference given to species and habitats, NCPs, climate-change resilience, and ecological connectivity.

We find that variations in the area sharing of conservation, strict protection and restoration among countries and biogeographic regions lead to the largest spatial changes among scenarios (Figure

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10). For example, European-wide priorities with no area sharing constraints led to disproportionately selecting priority areas for PA expansion in the Mediterranean (e.g. Greece, Spain, Portugal) and Alpine biogeographic region. By contrast, area sharing among biogeographic regions leads to selecting priority areas for conservation in the Atlantic bioregion, in the Apennines, and in the Baltic states (Figure 10 & Figure 11).

In terms of performance, we found that the Nature for Nature and Nature as Culture variants both systematically outperformed Nature for Society across all indicators of performance, except for carbon and NCP where Nature for Society was associated with higher gains (Figure 10). Nature for Society performed notably worse in terms of strict protection benefits for species, habitats and climate-change resilience. Biogeographic regional level sharing of area allocated to 30% conservation leads to worse performance than under country-level sharing or European wide priorities without area sharing, particularly for species and habitats of conservation concern. This is because the Mediterranean region, Alpine region, and Macaronesia already have a dense protected area coverage close to or above 30% of their bioregional land area; yet, many biodiversity features remain insufficiently protected within these regions. We found that planning explicitly for climate change resilience increased the performance of conservation, strict protection and restoration areas in terms of selecting top climate-change resilient areas, with no trade-offs for other performance indicators. Likewise, explicitly considering ecological connectivity led to higher gains for ecological corridors in conserved and restored areas. Explicitly planning for ecological connectivity for achieving 30% conservation however led to slightly lower gains for climate resilience in areas selected for enhancing connectivity.

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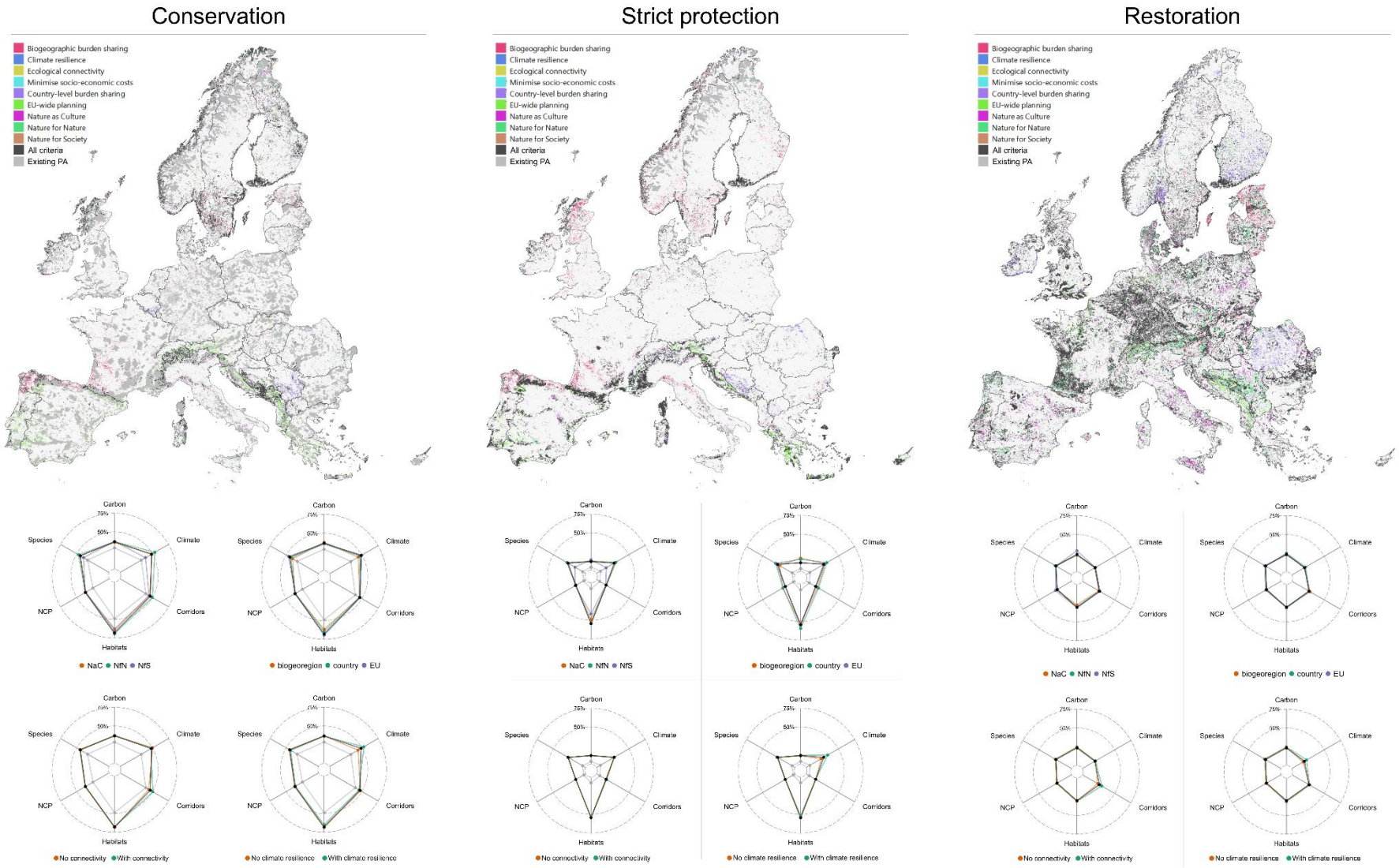

Figure 10: Trade-offs and synergies among planning criteria for conservation, strict protection and restoration.
The maps show consensus priorities among all criteria in dark grey, existing protected areas in lighter grey, and diverging priorities for individual planning criteria in colours. The radar plots show the performance indicators associated with each planning criteria, represented in different colours, with the performance of the consensus priorities in black, and grey lines indicating the performance within existing protected areas.

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Sharing of land area allocation among countries and biogeographic regions across variants. We found that there was considerable variation in the amount of area selected per country or biogeographic region across different variants. This variation was primarily driven by the area-sharing strategy implemented in the pan-European prioritisation. In the absence of constraints limiting the expansion of protected areas to 30% of their area, several biogeographic regions and countries appear to have exceptional pan-European value for conservation and strict protection relative to their total land area: for example, the Alpine, Mediterranean and Macaronesian regions; and countries such as Albania, Greece, Cyprus, Italy, Spain, Portugal, Montenegro, Croatia, Slovenia, Austria, Switzerland, Andorra. While designating more than 30% of land area to conservation is beyond the scope of most National Biodiversity Strategies and Action Plans, this result points to the need for sustainable management of ecosystems in these regions and countries with exceptional value for the protection of pan-European biodiversity and NCP, and opportunities for 2050 biodiversity commitments.

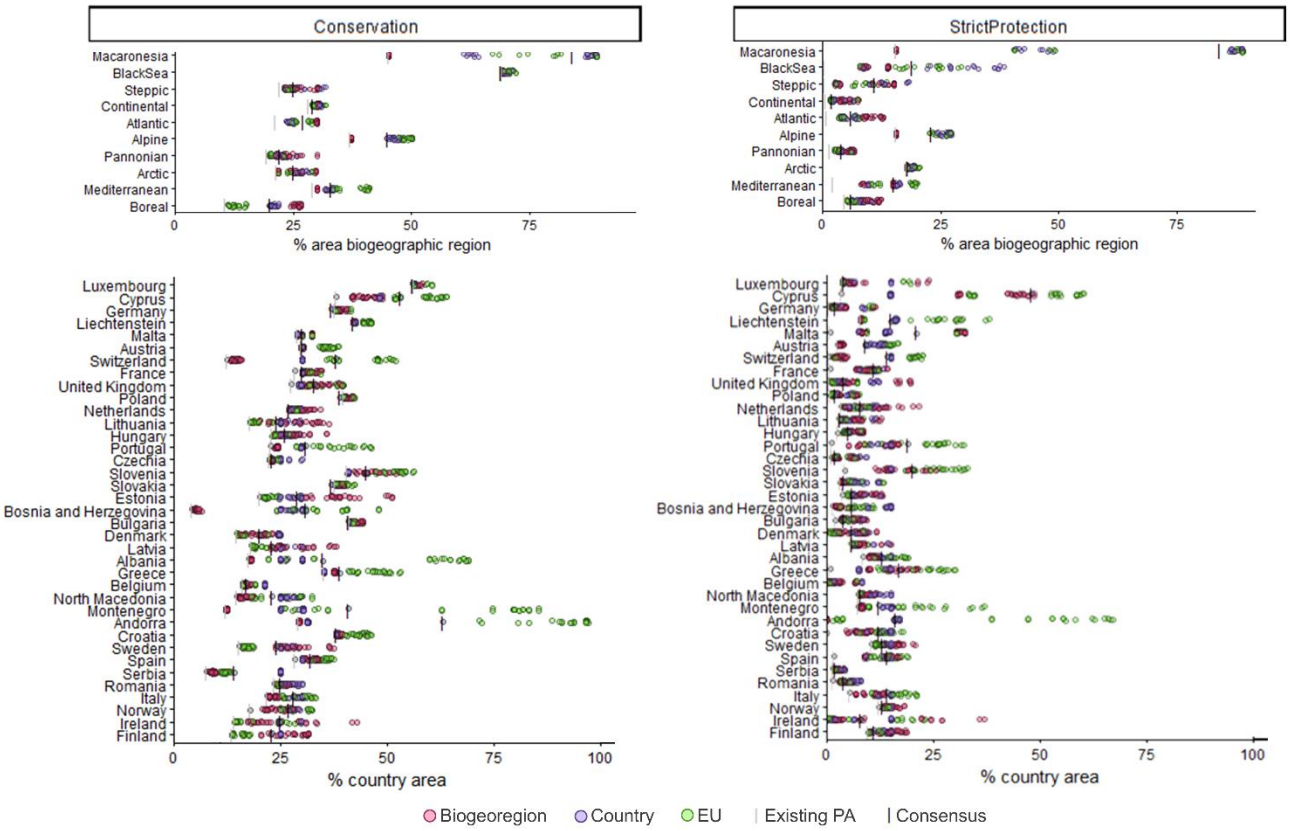

Figure 11: Area allocation for conservation and strict protection among bioregions and countries across all variants. The jitter plot shows the % area selected for conservation or strict protection per country of biogeographical region. Each dot represents an individual variant, coloured by the area-sharing strategy, i.e. whether to ensure area-based targets for 30% conservation and 10% strict protection are achieved at the level of countries, biogeographical regions, or at the EU level. The bars represent the % area per country or biogeographic region covered by existing protected areas (in grey) and by top priorities in the consensus map (black).

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3.4. Implementation challenges and opportunities

3.4.1. Opportunities for enlarging, strengthening, and restoring current protected areas

Enlarging existing protected areas may be easier in some cases that designating entirely new protected areas. We found that 33% of the top priorities for 30% enlarge existing protected areas, while 67% of the priorities are new designations. Likewise, for achieving 10% strict protection objective across Europe, upgrading existing non-strictly protected areas are sometimes considered more feasible than a new designation for strict protection in a previously unprotected area. The majority (65%) of top priorities for strict protection identified here consisted in an upgrade of existing non-strictly protected areas, due to region-constraints on strict protection (Figure 12). Note that only 4% of top priorities for strict protection enlarge existing strictly protected areas. This highlights that the top priorities for strict protection expansion do not perpetuate the biases in the location of strictly protected areas in Europe, instead increasing strict protection coverage in biomes and ecosystems that currently are underrepresented by strict protection.

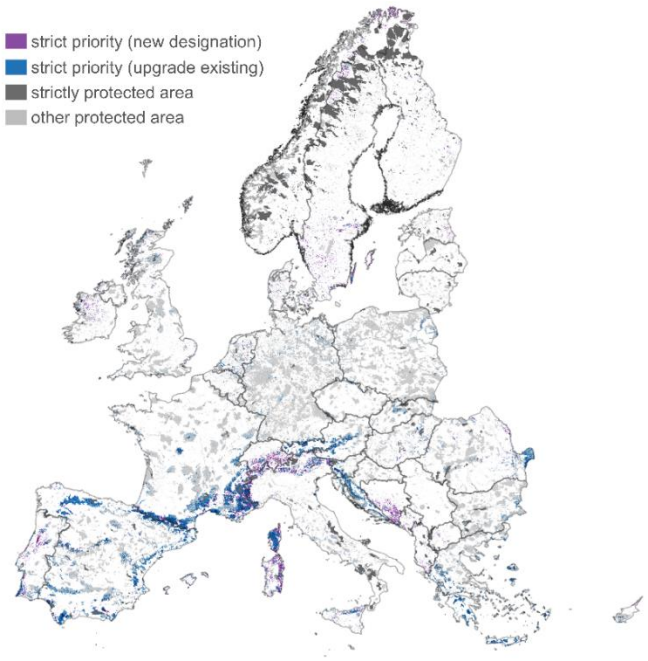

Figure 12: Priorities for upgrading existing protected areas to strict protection.
The map shows strict protection priorities with a distinction between priority areas falling within existing non-strictly protected areas (i.e. upgrade existing PA, in blue) and outside (new designations, in purple). Strict protection priorities for 10% expand on existing strictly protected areas (in dark grey). Other non-strictly protected areas not selected as priorities for strict protection are shown in light grey. Note that coloured areas might be visually overrepresented in the figure (the planning unit grain is 1 km²).

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Similarly, the restoration of currently degraded protected areas could be more feasible and biodiversity beneficial than restoration of areas outside existing protected areas, due to there being often more resources and capacity for undertaking restoration interventions when existing protected areas are currently in place. We found that about half of all pan-European restoration priorities identified are within existing protected areas. Many of these existing degraded protected areas that had potential for ecological restoration were distributed in the Continental and Atlantic biogeographical regions, and predominantly in Germany, Poland, France, and England. In terms of performance, we found that restoration priorities both within and outside existing protected areas provided similar levels of potential benefits for biodiversity, NCP, carbon, climate resilience and ecological connectivity (Figure 13), suggesting that we need restoration both within, and outside, protected landscapes.

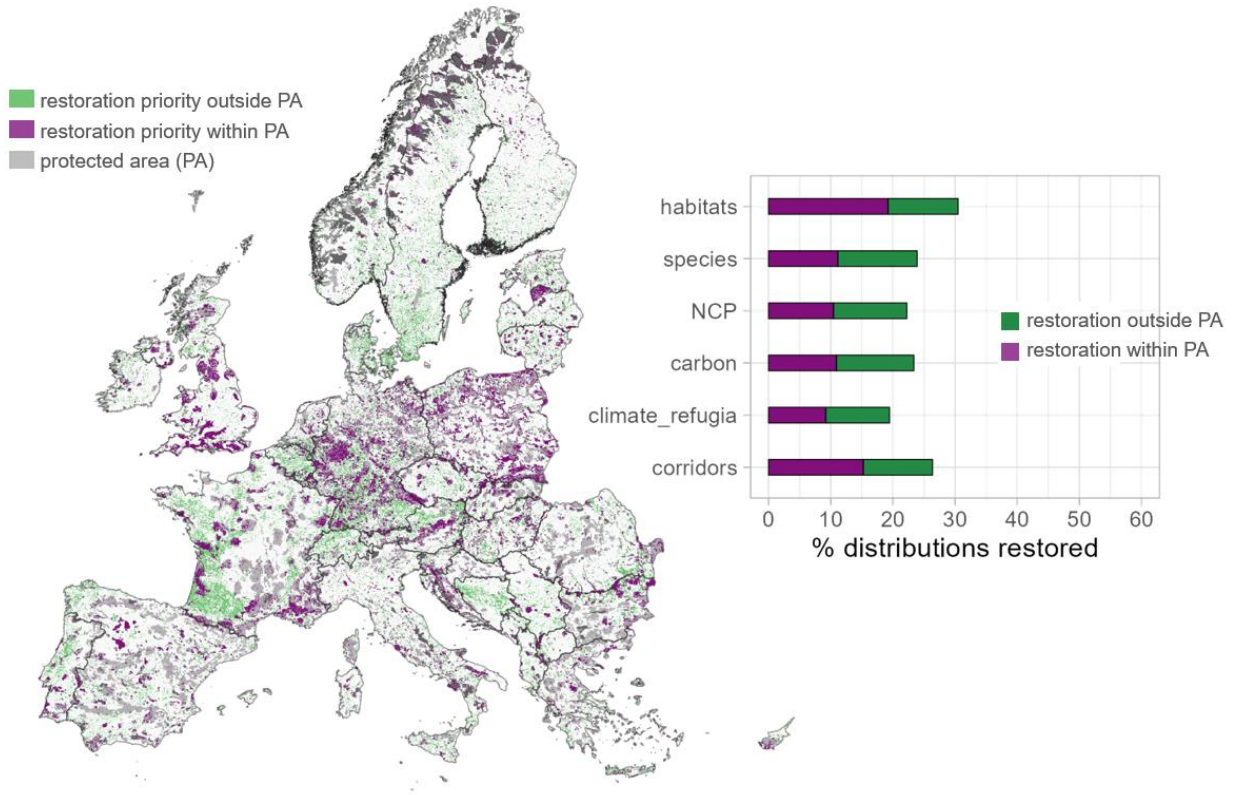

Figure 13: Consensus priorities for 20% restoration. Colours represent the distinction between priorities within (purple) vs outside (green) existing PA. The barplot indicates the percentage of potential distributions for biodiversity and NCP (relative to their total amount) that would be restored.

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3.4.2. Potential conflicts between conservation and land use and opportunity costs

On average, opportunity costs associated with expansion priorities to reach 30% protected area coverage were €23.40/ha for forestry and €32.20/ha for agriculture, providing insights about their socio-economic feasibility. The consensus priorities for 10% strict protection were associated with average opportunity costs of €18.10/ha for forestry and €28.20/ha for agriculture, i.e. approximately €4.65/ha lower compared to the consensus priorities identified under the 30% conservation objective.

Additionally, we found that 29.8% of priorities for protected area expansion fell within areas of productive land use (Figure 14). Specifically, 7.6% of priorities for protected area expansion overlap with medium to high-intensity croplands; 1.9% of priorities overlapped with medium to high-intensity grasslands; and 20.2% of priorities overlapped with medium to high-intensity forest systems.

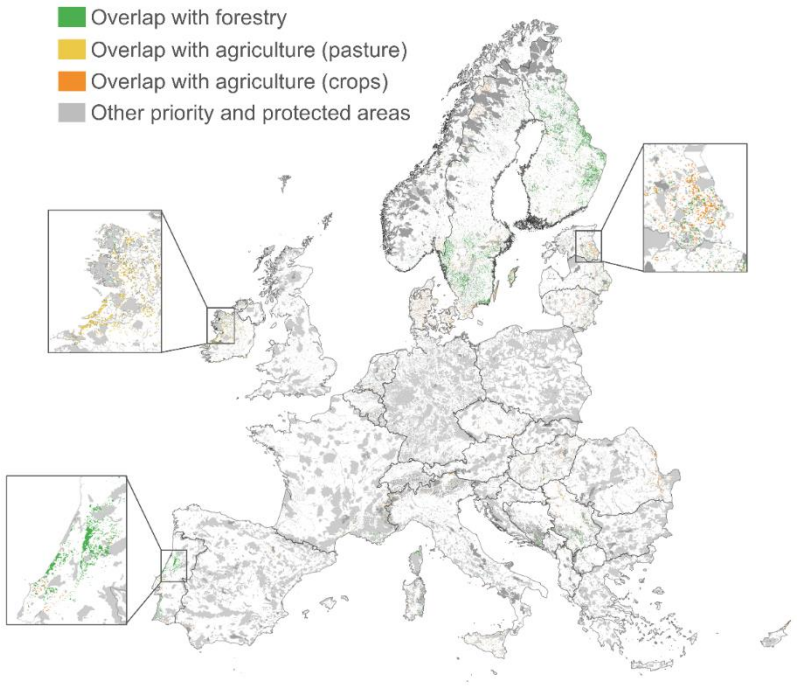

Figure 14: Potential conflicts between priorities for protected area expansion and productive lands. Coloured areas on the map highlight the overlap between conserved areas (including existing protected areas and expansion priorities), and medium- to high-intensity classes of forestry, croplands and grasslands in the European land systems map. Gray areas represent existing protected areas and expansion priorities that do not overlap with medium to high-intensity systems. Note that coloured areas might be visually overrepresented in the figure (the planning unit grain is 1 km²).

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3.4.3. Transboundary priorities

Designating areas for protection and restoration is a national responsibility, yet there are considerable benefits to regional cooperation across jurisdictions (Kukkala et al., 2016; O'Connor et al., 2024; Visconti et al., 2024; O'Connor et al., under review). Many areas that would bring the greatest benefits often fall on geographic areas that are shared between countries, such as mountain ranges and other natural geographic boundaries. Such areas would naturally lend themselves for cross-border collaboration, joint designation and management, and to overcome the challenges of coordinating conservation and restoration action across jurisdictions. To identify those areas with the highest priority for conservation and restoration, we overlaid the consensus layer with existing PA (covering both Natura 2000 and CDDA) and a 10 km transboundary buffer.

Approximately 11.0% of all existing protected areas are located within this 10 km transboundary region (Figure 15), with 36.1% of all transboundary area already under some form of protection, higher than the 24.9% of protected land area in Europe. Notable hotspots of existing transboundary protection occur along the national borders of Spain & France, and Poland & Slovakia (Figure 15). Using the same analyses to assess the consensus solutions, we find that in total 42.4% of transboundary area would be protected (existing PAs + consensus priorities) in reaching the 30% protected area target. Considering that PA expansion priorities amount to 274,346.7 km^2, or 5.4% of the planning region, we would expect 5.4% of transboundary regions (which total 382,885.9 km^2, or 7.58% of the planning region) to be identified as an expansion priority if priorities were allocated at random. Instead, we find that ~6.5% of all transboundary area was identified as an expansion priority (19.65% higher than expected by chance), underscoring the importance of transboundary regions not only for the management of existing protected areas, but also for the future implementation of policy targets.

Similarly for 10% strict protection, we find that 11.9% of consensus areas (existing PAs + consensus priorities) were located within the transboundary region, with 15.6% of transboundary areas being strictly protected. Following the prior logic, these findings suggest that strict expansion priorities (expansion only) are 47.2% more likely to occur within transboundary regions compared to what would be expected at random, meaning transboundary regions play a disproportionately larger role in meeting strict protection targets across Europe.

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When considering all top priority areas for conservation, strict protection, restoration and ecological corridors that compose the TEN-N, we found that 62% of all transboundary regions are a consensus priority for at least one of these objectives.

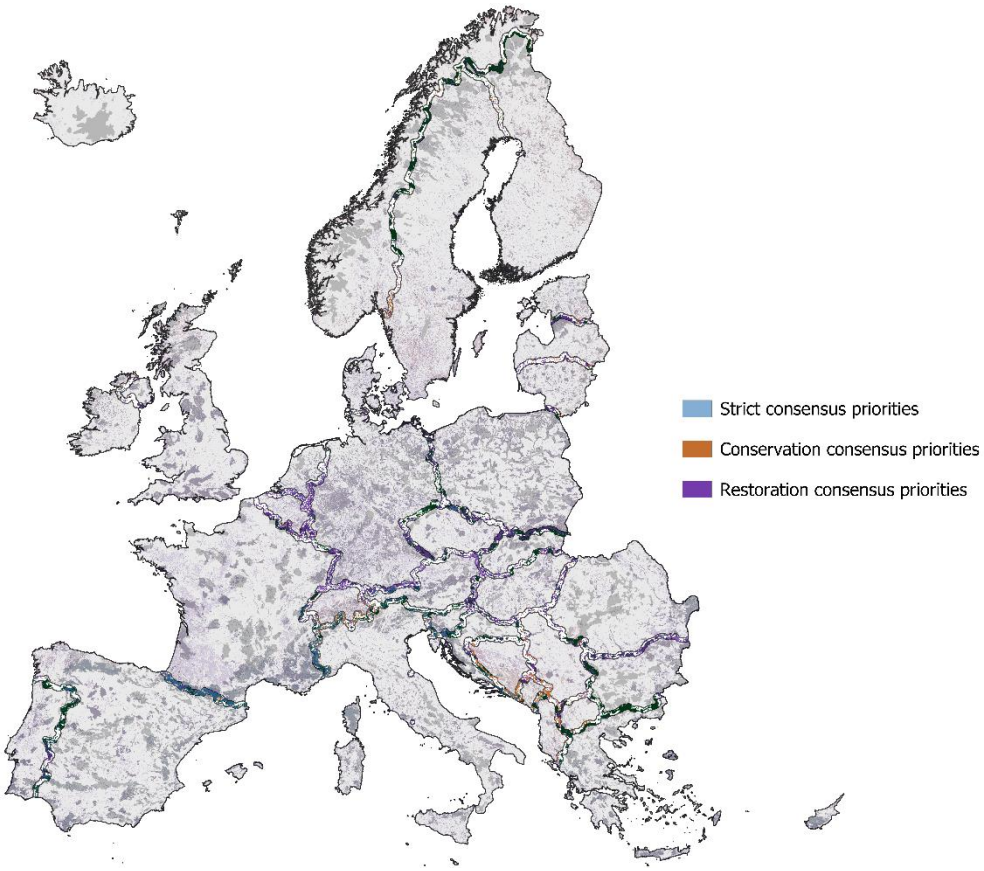

Figure 15: Transboundary priorities for conservation, restoration and strict protection.
Existing protected areas (grey) located within transboundary regions (green) are also shown. Note that coloured areas might be visually overrepresented in the figure (the planning unit grain is 1 km²).

3.5. Results of the scoping for Key Biodiversity Areas

We present here a summary of the key results derived from the scoping of potential KBAs in Europe. The full results are presented in a separate report.

3.5.1. Scoping of existing KBAs

A total of 3,821 existing KBAs occur in the WDKBA for the 39 countries covered by the NaturaConnect project. Most of these are IBAs, Critical Ecosystem Partnership Fund KBAs (identified before KBA criteria were finalised) and Alliance for Zero Extinction (AZE) sites. These

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KBAs currently cover 19.6% of land in Europe and 11.2% of the exclusive economic zone (EEZ) of countries that have jurisdiction over parts of the sea.

Currently 836 (21.9%) of these KBAs are recognized as Global KBAs, mostly for bird species (IBAs). Of the remainder, 2,520 (66.0%) are considered regional KBAs for the species listed for the sites, meaning that existing data suggest that they do not meet the global KBA criteria. As defined in the KBA standard, these sites are treated as regional KBAs. There is currently insufficient data in the WDKBA for the remaining 465 (12.2%) to determine their global/regional status.

Our scoping of all existing KBAs indicates that a significant number would potentially qualify as global KBAs (Figure 16). We estimated that 2,538 (66.4%) of the existing KBAs could potentially qualify as Global KBAs (under criteria A1, B1, B2 and/or B3), if all taxonomic groups included in the scoping tool were assessed. However, 836 existing sites qualify as Global KBAs under criteria that the scoping tool cannot currently apply (e.g. D1a for aggregations of species which requires numbers of mature individuals, not area-based estimates of the population). Of these, 310 sites are not among the sites identified as potentially global KBAs in the scoping analyses. Therefore, including all existing global KBAs with those identified as potential global KBAs would increase the number of existing KBAs in Europe that already or potentially could qualify as global KBAs to 2,848 (74.5%).

Currently, 186 species qualify existing KBAs as global KBAs across Europe, of which 142 (76.3%) are bird species. The scoping of all these KBAs indicates that 3,915 species assessed on the IUCN Red List potentially qualify sites as KBAs, which includes 49 of the existing species that qualify sites. This identifies potentially 4,052 species that currently or potentially qualify existing KBAs across Europe.

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Figure 16: Existing Key Biodiversity Areas that may qualify as global KBAs (dark green) based on results of the KBA scoping tool. KBAs that would not qualify as global sites as assessed by the scoping tool were more common in northern Europe (purple).

3.5.2. Scoping of existing protected areas and OECMs

We scoped 166,116 protected areas and OECMs across Europe of which 157,479 (94.8%) are terrestrial and 8,673 (5.2%) marine or coastal. Many of these sites overlap with each other, which makes the analysis of the data, and particularly area of coverage more complicated. We therefore dissolved all of the protected areas into one layer that was used to calculate coverage values. On average, protected areas cover 25.5% of land and 16.8% of seas per country using our GIS-based calculation of cover.

Of these existing protected areas, 19,655 (11.8%) are completely within KBAs (>98% cover), 21,429 (12.9%) are partially covered by KBAs (2-98%), and the remaining 125,032 (75.3%) are outside any KBA (<2% cover). Assessing the numbers of KBAs that are covered by protected areas we find 1,514 (39.6%) are completely covered by protected areas, 2,122 (55.5%) are partially protected (2-98% cover), and only 186 (4.8%) are completely unprotected (<2% cover).

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If we assess the total area of KBAs at a country level, we find an average of 76.8% of the area of KBAs per country are currently covered by protected areas.

Our analysis identified 16,450 (9.9%) protected areas that might qualify as global KBAs, of which 12,468 (7.5%) are additional to existing protected areas that are fully covered by KBAs. Of these, it is predicted that 8.9% of the number of terrestrial protected areas and 27.8% of coastal and marine protected areas would qualify as global KBAs. Many protected areas in Europe are small, however, and when area of protected areas and KBAs is compared, we find that it tends to be the larger sites that are potential KBAs (Figure 17). If confirmed as KBAs these sites would add an additional 3,033,675 km² of protected area that would be recognized as KBA, about 65.8% of the extent of all protected area across Europe. Combined with existing KBAs, the extent of KBAs in protected areas could reach 79.4% of all current protected area coverage. Of this, 71.6% of terrestrial and 87.6% of coastal and marine surfaces of protected areas could potentially qualify as KBAs. The mean percentage area of each country that currently or potentially might qualify as global KBAs is 69.6%.

The scoping of all protected areas in Europe identified 5,776 species as potentially qualifying one or more sites as a KBA. Of these, 3,797 species also were potential qualifying species for the KBA scoping (above), and 1,979 species were additional to those that potentially qualify existing KBAs. An additional 30 species only qualified existing KBAs but did not qualify any protected areas.

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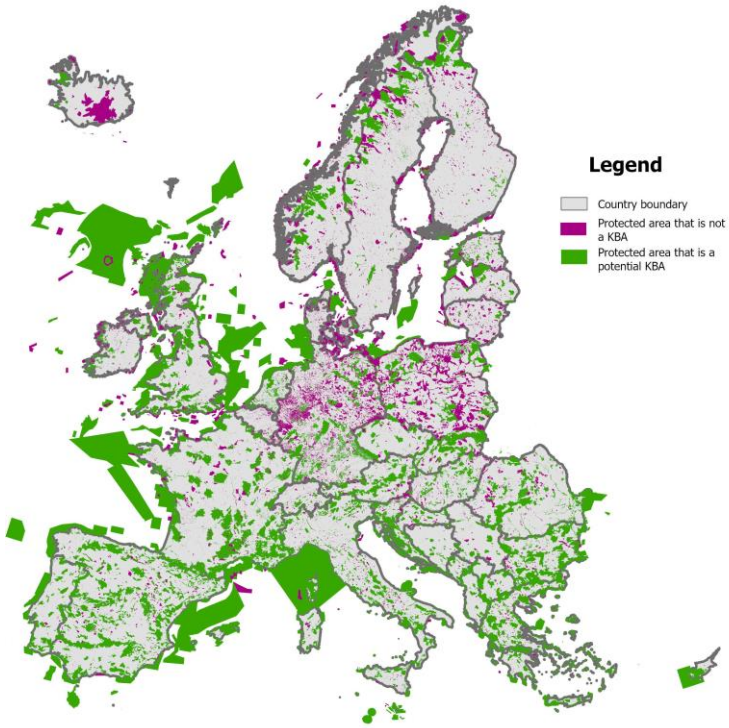

Figure 17: Scoping of existing terrestrial and marine protected areas in Europe identifying those protected areas that potentially qualify as global KBAs (dark green)

3.5.3. Scoping of NaturaConnect solution

The NaturaConnect planning process developed more than 100 scenarios with different solutions that identified where to prioritise conservation. We analysed a harmonized consensus solution layer which covered an area of 2,223,601 km². Much of this solution falls within existing protected areas (70.0%) with 666,134 km² (30.0%) falling outside. Analysing the area of the NaturaConnect solution outside both KBAs and protected areas together we find that only 605,267 km² (27.2%) falls outside both. A scoping of the NaturaConnect solution that falls outside the existing protected area network identified 308,576 km² (46.3% of the area outside protected areas) that could potentially qualify as global KBAs (Table 5). These sites mostly are found in southern Europe (Figure 18).

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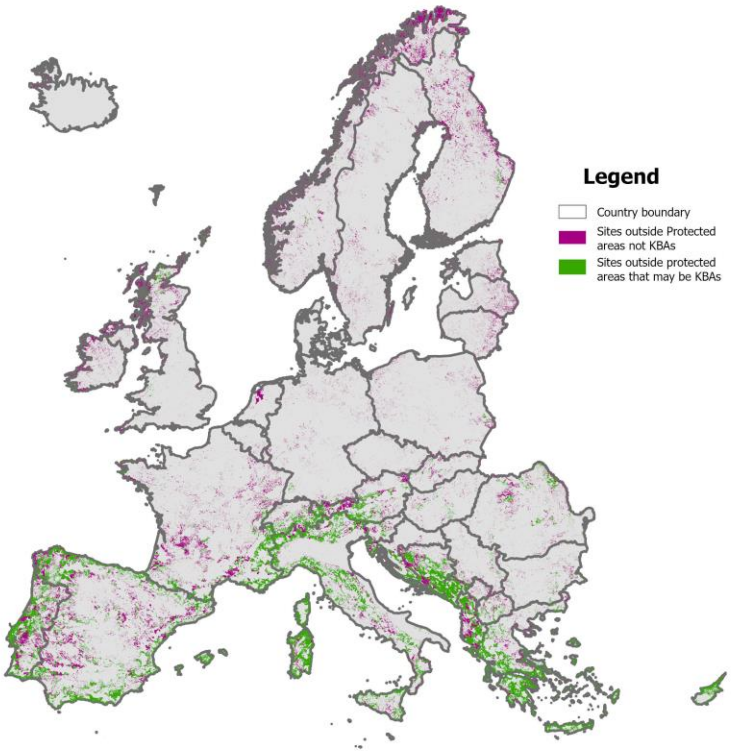

Figure 18: Scoping of the NaturaConnect harmonised consensus solution focusing on the area of the solution outside existing protected areas. Those that potentially qualify as global KBAs are dark green.

Table 5: Areas and percentage of the NaturaConnect (NC) harmonised solution and those areas that might potentially qualify as KBAs based on the scoping analysis.

Analysis result	**Total area (km²)**	**Percentage of total NC solution**	**Potential Global KBA area within this set (km²)**	**Percentage of this set that may be KBAs**
Total NC solution (including existing protected areas)	2,223,601	100.0	989,457	44.5
Existing Protected Areas (PAs) in NC solution	1,557,467	70.0	617,201	39.6
Existing KBAs in NC solution	772,594	34.7	371,979	48.1

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Protected area expansion priorities (NC solution outside protected areas)	666,134	30.0	308,576	46.3
NC expansion priorities not currently recognized as KBAs	605,267	27.2	269,616	44.5
NC expansion priorities that are not potential KBAs	335,651	15.1	0	0.0

We break down the analysis of the harmonized NaturaConnect solution in Table 5. Here we look at the proportion of the whole solution that might be identified as KBAs, the proportion of the solution within protected areas and existing KBAs that might qualify as KBAs using the same scoping method we applied to the solution outside these areas. Overall, as much as 989,457 km^2 of the 2,223,601 km^2 harmonised solution potentially qualifies as globally important (45%).

A total of 3,726 species potentially could qualify sites outside the existing protected area network as KBAs based on the scoping analysis. Many of these are also species that could qualify existing protected areas and KBAs. Only 63 species are unique and were not potential KBA species for the protected area or KBA network. Of these 48 species are molluscs, seven are plants and six are arthropods. A combined total of 5,869 species could potentially qualify sites within protected areas, KBAs and outside these networks across Europe. These include only the species assessed on the IUCN Red List of Threatened Species and there will likely be other species, particularly plants, invertebrates and fungi, that could qualify sites as KBAs that have not been assessed on the IUCN Red List and therefore are not incorporated in the KBA scoping tool. Given that currently only 186 species qualify global KBAs across Europe, there is significant work needed to update Europe's KBA networks and qualifying species.

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4. Discussion

4.1. A blueprint for the Trans-European Nature Network (TEN-N)

We developed a blueprint for achieving international biodiversity objectives for conservation (all protected areas), strict protection and restoration in Europe. These objectives may overlap (protected areas and restoration actions) or be mutually exclusive (a protected area can either be strictly protected or not). The overall benefits of allocating these three area-based conservation measures depend on the extent to which these actions are planned synergistically and in ways that are ecologically meaningful (comprehensive, climate-resilient, connected). In other words, achieving the overarching goal of the EU Biodiversity Strategy of reversing biodiversity loss through area-based conservation targets benefits from such an integrated blueprint. The spatial planning approach developed here does not only provide a more comprehensive, adequate and resilient solution to changing climate and land-use, but it is also feasible and policy-relevant (including equitable area sharing among European countries and considering socio-economic costs).

Our results with the integrated spatial priorities highlight the need for cross-border coordinated planning, recognising shared responsibilities towards conserving and restoring biodiversity. In particular, the importance of coordinated planning across borders is illustrated by the fact that **42.4% of area within transboundary regions in Europe are priorities for the TEN-N** when considering a consensus TEN-N map, and 62% are considered priority in at least one TEN-N scenarios. This is a strong empirical case for why cross-border coordination should be regarded as necessary for the protected area network to function. Mechanisms such as the **Alpine Convention, Carpathian Convention,** and **Emerald Network with non-EU countries** should use to promote the protection of these high-priority transboundary regions through expansion of existing PAs boundaries or new designations where appropriate. Furthermore, it will be important to assess which **border regions have high ecological priority but low existing institutional cooperation**. Transboundary designation could help close the remaining gap to 30% and 10% targets, since much of the area is already under some protection and the marginal addition is modest. Thus, cross-border coordinated planning can help improve the effectiveness of conservation and restoration for biodiversity.

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It is well established that pan-European coordinated planning delivers higher benefits than independent national-level planning in terms of biodiversity representation (Kukkala et al., 2016). Yet, our analyses revealed that **national-level planning that account for the national responsibility of countries** to protect the species and habitats **can be almost as efficient as a pan-European prioritisation** with balanced national area sharing (O'Connor et al., 2024; O'Connor et al., under review). In other words, priorities for protected area expansion established with national or subnational analyses can be almost as effective for global biodiversity conservation, as long as national analysis of priorities for protected area expansion account for species' and habitats' entire distributions and the national responsibility towards protecting these species and habitats. This avoids identifying as national priorities areas hosting species or habitats at the margin of their distribution, relatively rare and range-restricted within a country, but common outside the country border. Instead, this approach ensures that each country protects a similar amount of area but focusses on regions which are strategically important at European level to protect habitats and species in the core of their distribution.

Our analyses show, unsurprisingly that priority for area-based conservation measures that aim to conserve culturally significant habitats and species, or regulating Nature Contributions to People, do not overlap with those specifically addressing gaps in protection of species and habitats of European Conservation Concern, with an average decline in representation of habitat for species, or extent of habitat by ~10% when shifting from species and habitat focussed prioritization (Nature for Nature scenario) to cultural, regulating and provisioning Nature Contribution to People (Nature as Culture and Nature as Society). The geographic priorities also shifted somewhat, especially for what concerned the allocation of strictly protected areas. This suggests that, while consensus areas identified here are safe bets to inform local and national planning of protected area expansion, as they provide multiple benefits; other areas, flagged by only one or few scenario variants should not be immediately discounted as unimportant. The value of these areas in supporting national and local conservation planning will depend on the alignment between the value perspective of the respective scenarios, and national planning goals and consequent interpretations of the role of area-based conservation measures in delivering benefits to habitat and species or NCPs. This was exemplified by several interactions had with stakeholders during the iterative production and expert-validation of these spatial priorities. For instance, in one of the NaturaConnect stakeholder workshop, the Nature for Society and Nature as Culture scenarios were particularly well received by Belgian participants because they resulted in a more ambitious and geographically distributed TEN-N network, consistent with stakeholders' expectation that

protected areas should be readily accessible to a large share of the population. These findings further strengthen the importance of exploring several variants, and transparently communicating their multi-dimensional performance, across all ecological and socio-economic metrics considered of relevance.

Our findings highlight that Member States could use systematic prioritisation outputs like the TEN-N consensus maps as a basis for planning for protected area expansion to achieve target 1 and 2 of the EU BDS and target 3 of the KM. This approach is potentially able to achieve 3-10x higher representation of under-protected habitats and species than existing protected areas. The geographic concentration of consensus priorities (Alpine, Mediterranean, islands), indicates that **targeted EU co-financing (LIFE, futures NRR implementation funds and INTERREG)** should be prioritised in these regions specifically for strict-protection upgrades, rather than spreading designation effort evenly across biogeographic regions.

Member State reporting under the Biodiversity Strategy could demonstrate that new area added toward the 30% target is prioritized with robust ecological evidence (species, habitat, carbon, NCP, climate resilience, connectivity) rather than protecting the least-contested land. Calls based on biodiversity-naïve surrogates of ecological value such as roadless areas as a basis for strict protection may be inefficient. Our analyses revealed that by optimizing explicitly for biodiversity features under constraints, the top priorities we identified for reaching 10% strict protection in Europe outperforms roadless areas, while covering the same amount of land (O'Connor et al., in preparation). These roadless areas are associated with 2 to 3 times lower representation of European biodiversity, habitats and carbon-rich ecosystems compared to the strict protection priorities we identified by explicitly optimizing for ecological benefits under constraints. Roadless areas in Europe are not sufficiently representative of European diversity: these areas are typically located in remote areas, high elevation or high latitude, which only represent a subset of all ecological conditions across Europe and thus a subset of its biodiversity. While we find that roadless areas have 50% higher coverage of areas in the top decile of ecological integrity (low human appropriation of NPP, high trophic interaction diversity and low fragmentation) these areas are particularly concentrated in boreal forests, Iberian grasslands and shrubs and this leads to suboptimal results in terms of the benefits and gains of new areas of strict protection for species, habitats, carbon-rich ecosystems, and climate refugia.

Thus, not all roadless areas in Europe automatically have ecological value, and using roadless areas alone as a basis for strict protection would be suboptimal for biodiversity protection. Our

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analysis showed that much higher biodiversity representativeness in areas of high ecological integrity can be gained from also placing strictly protected areas in non-remote areas. Moving forward, priority areas for strict protection that have also been identified as roadless, could be highlighted as being both highly feasible and highly valuable for strict protection.

We found that directing strict protection towards safeguard carbon-rich ecosystems (e.g., old-growth forests, peatlands, wetlands) can increase conserved carbon stock and sequestration potential by an average of 7.9% compared to present, and up to 13.9% if carbon storage and sequestration is given high priority (Nature for Society). These results demonstrate how TEN-N can substantially contribute to other environmental targets of the EU, including the target to increase the net carbon sink of the land-use sector to 310 $MtCO_2e$ (EU, 2023, Regulation (EU) 2023/839).

4.2. Scoping for Key Biodiversity Areas

Protected and Conserved Area coverage of KBAs forms the basis for several indicators for UN Sustainable Development Goals 14 & 15, as well as a disaggregation of the headline indicator for Target 3 in the Kunming-Montreal Global Biodiversity Framework. European countries are therefore asked to report on this indicator for these two multi-lateral agreements. Similar indicators using KBAs are used by the Convention on Migratory Species (CMS) and the Ramsar Convention on Wetlands.

KBAs are also identified as 'biodiversity sensitive' areas in the Environmental Sustainability Reporting Standards (ESRS 4) of the Corporate Sustainability Reporting Directive (CSRD), as well as in the EU Taxonomy. KBAs are being used by most banks to screen requests for lending by business through the Integrated Biodiversity Assessment Tool (IBAT). As a result, companies are required to avoid or minimize negative impacts on KBAs and to monitor their impacts at KBAs where they operate. They are also required to assess impacts on KBAs in their value chains. This is not possible to do completely if not all KBAs have been identified in each country.

Our results show that many priorities for protected area expansion (between 67-80% of sites) are not identified yet as global KBAs and are not available for business to use in the World Database of KBAs and IBAT. They also show that as much as 45% of the regional NaturaConnect plan is of global significance also and therefore an even greater imperative to conserve.

If Goal A of the GBF, which aims to halt human-caused extinctions by 2030 is to be achieved, then the recognition of sites with globally significant populations of one or more species or globally significant extents of an ecosystem is essential to guide governments, business and the funding for conservation. KBAs networks should therefore be updated by 2030 and then the KBAs identified considered in national policies and legislation to support their long-term conservation.

4.3. Limitations and perspectives

This NaturaConnect planning exercise includes a wide breadth of taxa (vertebrates, plants and invertebrates), habitats and NCP, but the biodiversity features considered were restricted to those that are of direct relevance to European policy frameworks. While this ensures direct policy relevance of our results, studies suggest that a narrow focus on listed features is suboptimal for representing broader biodiversity (Virtanen & Moilanen, 2023), particularly given that EU policy frameworks are biased in their representation of taxa: the Annexes of the two Nature Directives, with a majority of native birds and other vertebrates respectively included in Annex I of the Birds Directive and Annex II of the Habitats Directive but only a small fraction of all native plants and invertebrates species in Europe included in the latter (Si-Moussi et al., 2025). Having accounted for IUCN Red List assessments somewhat correct this for this bias, but not entirely, because not all plants and invertebrates groups have been comprehensively assessed in Europe [1]. Furthermore, this may miss some species that require conservation even if not classified as threatened with extinction, and/or that could become threatened in the future, as well as non-threatened species that might be critical for the broader ecosystem stability and functioning (O'Connor et al., 2026).

Our prioritisation identifies areas of high pan-European importance for conservation, strict protection, restoration, but it does not prescribe the specific management actions, interventions or land-use changes that should be implemented within these areas. The priority maps should therefore be understood as decision-support tools for competent authorities involved in national and local planning processes, and not as prescriptive indications of new

[1] The following taxa are the only terrestrial groups for which all described species have been assessed in Europe: vertebrates, terrestrial and aquatic molluscs, dragonflies, butterflies, bees, grasshoppers, crickets and bush-crickets, hoverflies, trees, medicinal plants, bryophytes (mosses, liverworts and hornworts), and pteridophytes (ferns and lycopods). All other taxa and plant functional types have incomplete assessments (source: https://www.iucnredlist.org/regions/european-red-list)

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conservation areas and associated management zones. This distinction is important because the most appropriate interventions will depend on local ecological conditions, land-use histories, governance arrangements, stakeholder priorities and socio-economic contexts, many of which cannot be fully represented in a pan-European optimisation. Translating these priority maps into effective conservation and restoration action will therefore require engagement with local planning authorities, land managers, local communities and other relevant stakeholders, drawing on local expertise and participatory decision-making processes. First steps in this direction have been undertaken within the case studies in the NaturaConnect project (see D8.3) and with the development of a series of tools for validation and expert feedback elicitation (Jung et al., 2026). At the same time, the specific management choices made within priority areas are likely to strongly influence biodiversity and NCP outcomes, as explored in D5.3 for land-use zoning (Hackbarth et al., in review). This is likely to be particularly important in the case of restoration areas, here identified as areas currently used for forestry and agriculture but whose land-use intensity can be reduced to increase area of habitat for species, improve the extent and condition of habitat types of conservation concern, and increase the provision of NCPs. We did not prioritise specific restoration interventions and did not account for ecosystem processes and recovery dynamics which are central to restoration success. Future research and planning applications should therefore move towards jointly identifying priority sites and suitable management or restoration actions, particularly in local or regional planning exercises developed in dialogue with stakeholders (Jung et al., in preparation).

5. Use and application

The methodologies, pan-European prioritisation map outputs and indicators presented here were designed to support decision-making processes across scales and are relevant for multiple stakeholders involved in the planning of protected area expansion, strict protection, restoration, and green infrastructure in Europe. Altogether, these outputs provide a blueprint for planning and implementing European and international biodiversity policy targets, through the use of integrated cross-border spatial planning accounting for ecological and socio-economic factors.

The 144 TEN-N map variants presented here allow stakeholders to explore different scenarios of the TEN-N, examining trade-offs between ecological outcomes, climate resilience, and land-use pressures, and assessing how priorities change under different assumptions and emphasis given to a particular set of biodiversity features or other spatial planning factors. Furthermore, the

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combination of variants into one “consensus” prioritisation map helps stakeholders to identify ‘safe-bet’ areas consistently selected across all variants. The potential use and application of these outputs by different stakeholders are described below.

International policy makers and decision makers (e.g. European Commission, regional conventions, planning authorities, and NGOs) can leverage the prioritisation area outputs and indicators to inform European-level strategies and spatial priorities. They can use the results to identify and assess candidate sites for transboundary protected areas and other collaborative conservation initiatives, and to evaluate nationally proposed sites (e.g. Sites of Community Importance) or other types of sites (e.g. Emerald Network sites) for their ecological coherence and contribution to international biodiversity and conservation targets (Visconti et al., 2024). The mechanisms through which these pan-European analyses can be most informative are the Biogeographical Process.

In addition, the MTA metric has been proposed as a candidate indicator for the EU BDS dashboard to track progress in reducing gaps in coverage of species and habitats corresponding to EU BDS Subtargets 1.3 and 1.4 (European Commission Joint Research Centre and European Environment Agency, 2025b). A relevant example application at this scale is the Key Biodiversity Areas scoping exercise in Europe (see sections 1.4.2, 2.10, 3.4 and 4.5 of this report).

National authorities can apply NaturaConnect methodologies and prioritisation outputs to identify and target opportunities for expanding protected areas (including strictly protected areas), and scaling up restoration efforts in the context of goals and targets of the EU Biodiversity Strategy for 2030 and their Nature Restoration Regulation plans. By comparing different prioritisation scenarios, authorities can see how priority areas may change based on their planning objectives and assumptions, as well as assess the trade-offs between ecological outcomes. The country-level indicators on the NaturaConnector platform quantify benefits from existing protected area networks, as well as the potential gains in performance that could be gained from strategic protected area expansion.

Other types of stakeholders working on sub-national planning and implementation, such as **regional and local authorities, protected area managers, and non-governmental organisations (NGOs)** can use the prioritisation outputs to compare planning and management actions at site or regional level with broader EU-level policy goals, including which areas could be important from a broader EU perspective, or which areas of importance for protected area

expansion have also been identified as climate resilient. Additionally, actors in spatial, urban and transportation planning can use the results to ensure their planning and development activities are compatible with areas of importance for conservation or restoration.

Stakeholders from **land use sectors**, such as agriculture, energy, forestry, mining, and industrial development can use these tools to identify opportunities to reduce environmental impacts and contribute to conservation objectives. By understanding which areas have been identified as priorities for conservation and restoration, they can assess the current and planned locations of their operations and steer future activities away from areas of high conservation value. For example, there is an ongoing collaboration between the NaturaConnect project and **organisations** such as WWF-CEE who are using the prioritisation outputs to constrain renewable energy deployment models.

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6. Data availability

All data (priority variants, consensus maps) and code generated in the spatial prioritisation for conservation, strict protection and restoration is publicly available in Zenodo: 10.5281/zenodo.18863402. All 144 TEN-N scenario variants across Europe, as well as the country-level performance indicators are also viewable via the interactive online NaturaConnector web interface. Detailed descriptions of the performance indicators are provided in the form of indicator factsheets. These factsheets, in addition to all metrics calculated for existing protected areas and expansion priorities – across Europe and within individual biogeographic regions and countries – are available on Zenodo: https://doi.org/10.5281/zenodo.21904093. Summarizing factsheets per region (Country and biogeographic region) have been created for a brief overview of the various performance indicators for consensus conservation expansion priorities on Zenodo: https://doi.org/10.5281/zenodo.21728439

Maps of the outputs of the KBA scoping have been made available on the NaturaConnect resource platform for results. If countries are interested in specific results of the scoping for their protected areas, KBAs or NaturaConnect solution outside the protected areas please contact the KBA Secretariat (aplumptre@keybiodiversityareas.org).

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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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